

Overview of BNL Nuclear Theory Efforts

Members and recent personnel changes

Recent science highlights

Synergies with RBRC and HEP theory efforts

DOE Topical Theory Collaborations

BEST Collaboration

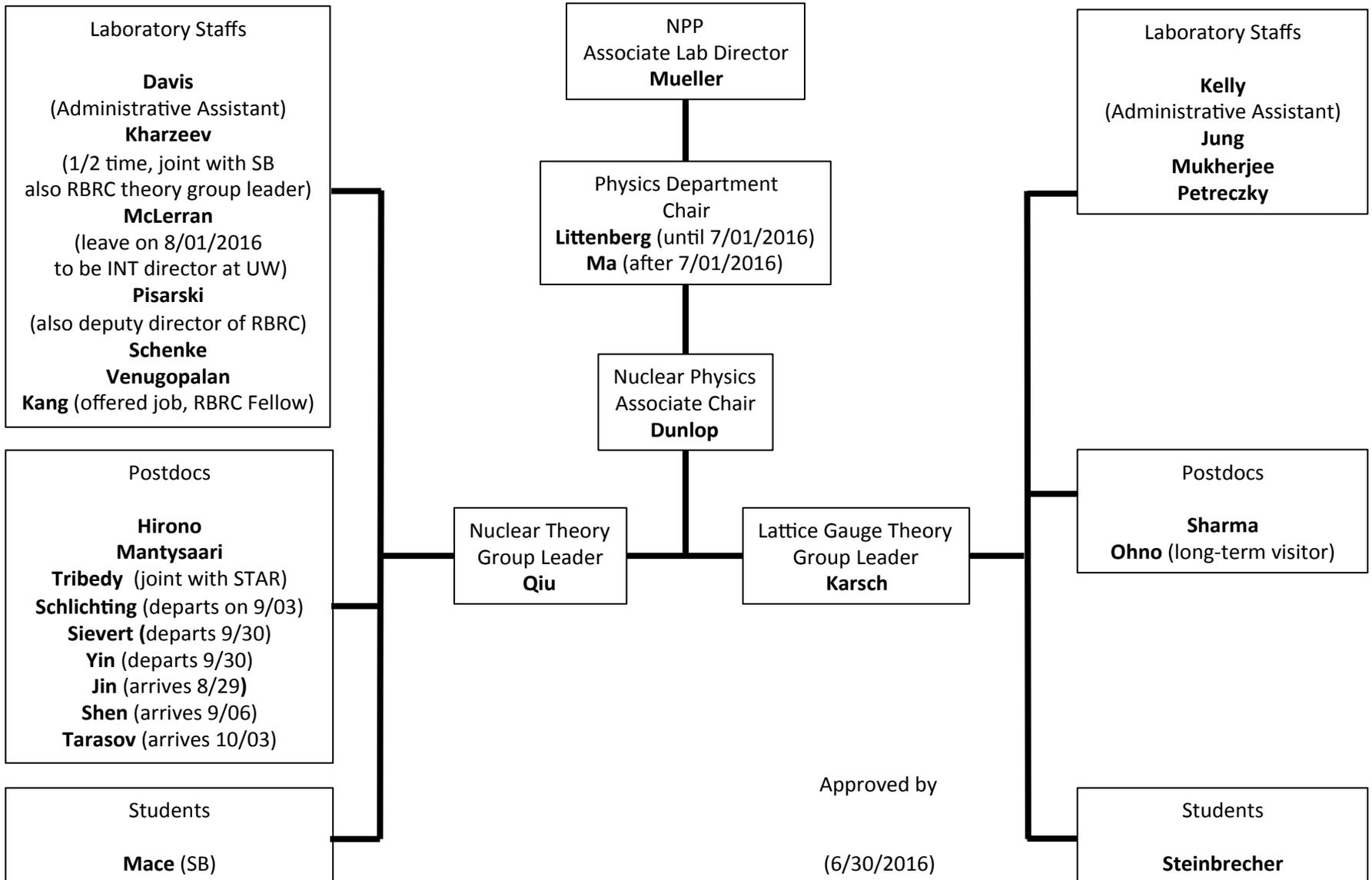
TMD Collaboration

Goals and deliverables

Jianwei Qiu

DOE RHIC S&T Review, August 23-25, 2016

BNL Organization Chart for Nuclear Theory Activities



Nuclear Theory Group (NTG)

Long term Scientific Staff:

D. Kharzeev (joint with Stony Brook)
L. McLerran (INT, UW, since Aug. 1st, 2016)
R. Pisarski
J. Qiu (Group Leader since July, 2015)
R. Venugopalan (Group Leader, 2010-2015)
B. Schenke (Associate Physicist)
Z.-B. Kang (Asst. Physt/RBRC Fellow(offered))

Group Administrator:

Dorothy Davis (80%)

Post-doctoral Fellows:

Y. Hirano (BEST), H. Mantysaari (ECA)
P. Tribedy (35%NT,65%STAR)
S. Schlichting (Goldhaber, leaves 9/3)
M. Sievert (EIC PDF, leaves 9/30)
Y. Yin (Leaves 8/31)
L. Jin (LDRD, arrives 8/29)
C. Shen (Goldhaber-ECA, arrives 9/06)
A. Tarasov (arrives 10/03)

Lattice Gauge Theory Group (LGT)

Long term Scientific Staff:

F. Karsch (Group Leader,
joint with Bielefeld)
P. Petreczky
S. Mukherjee
C. Jung (65%LGT,35%HEP)

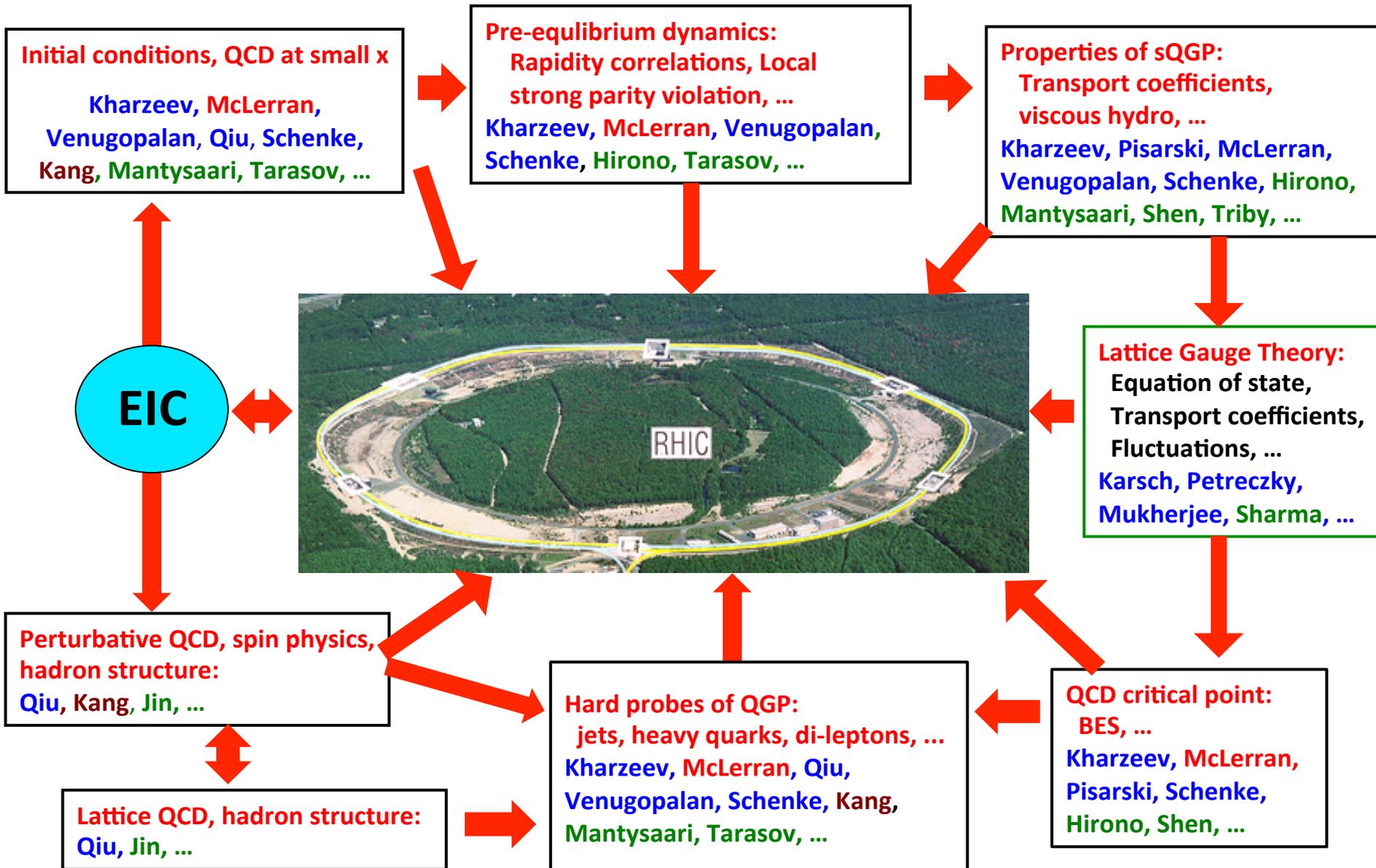
Post-doctoral Fellows:

S. Sharma
H. Ohno (Long-term visitor)

Group Administrator:

N. Kelly (35%)

RHIC Physics & Nuclear Theory @ BNL



Recent highlights and plans

Still too long

A quark summary of recent activity

❑ NTG Productivity (May, 2013 - June 2016):

Papers – 124 refereed papers including 25 letters

Invited Talks – 207 invited conference talks, plus colloquia and seminars

From the 5-year proposal
submitted for upcoming
DOE comparative review

❑ LGT Productivity (May, 2013 - June 2016):

Papers – 35 refereed papers including 7 letters

Invited Talks – 37 invited conference talks, plus colloquia and seminars

❑ NSAC Long-Range Planning process:

QCD Town meeting plenary presentations (Mukherjee, Qiu, Petreczky, Schenke)

Town meeting write-up (Hot QCD, Karsch, Venugopalan; Cold QCD, Qiu)

Major Whitepaper contributions (Karsch, Petreczky, Qiu, Venugopalan)

Resolution Committee (NSAC LRPWG, Venugopalan)

❑ DOE awards for Topical Nuclear Theory Collaborations:

BEST Collaboration – BES (Mukherjee – PI, Kharzeev, Schenke, Venugopalan)

TMD Collaboration – 3D imaging (Qiu – PI&Co-SP, Venugopalan)

A quark summary of recent activity

☐ Awards and honors (since May, 2013):

- D. Kharzeev:** Humboldt Award (2013), Severo Ochoa Prof., Madrid (2014)
- L. McLerran:** APS Feshbach Prize in Theoretical Nuclear Physics (2015),
PhD Honoris Causa at Jagellonian Univ., Krakow, Poland (2015)
- B. Schenke:** IUPAP Young Scientist Prize for Nuclear Physics 2013
DOE Early Career Award (2014)
- R. Venugopalan:** Research Excellence Prof. Award Heidelberg (2014-16),
EMMI Professorship (2014)

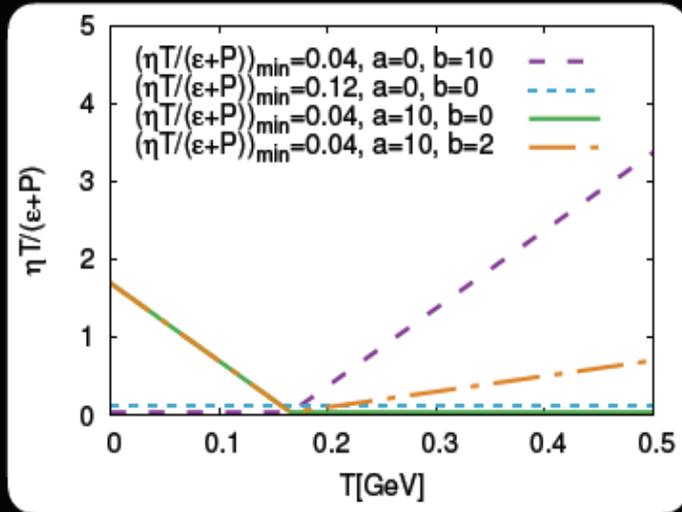
☐ Service (since May, 2013):

Group members served on International Advisory Committees of numerous major international conferences and workshops, organized many meetings, and lectured at many international summer/winter schools

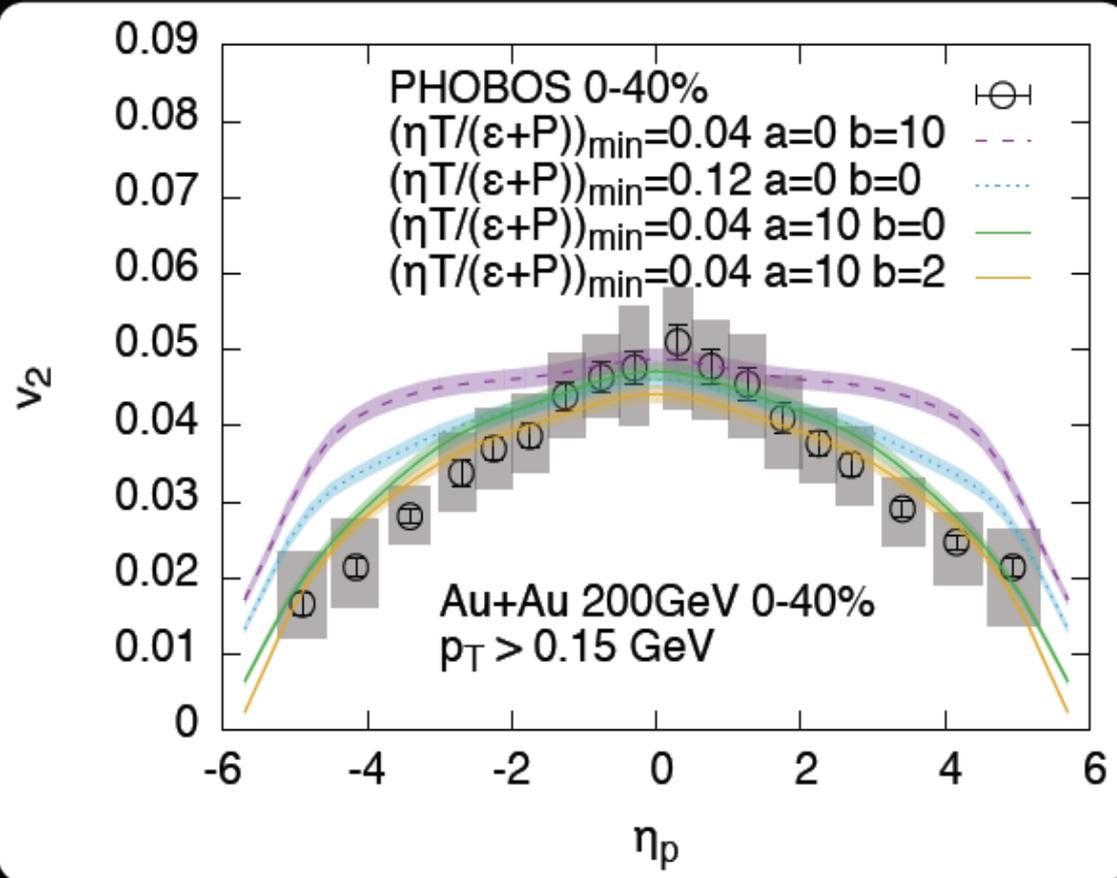
- F. Karsch:** Member of Executive Board of UKQCD
- D. Kharzeev:** Program committee of APS/DNP, Editor of Int. J. Mod. Phys. E
- R. Pisarski:** Associate Editor of Phys. Rev. D
- J. Qiu:** APS Fellow selection committee for APS/GHP (2015)
- R. Venugopalan:** NSAC, APS/DNP Executive Committee, Chair APS/GHP (2016)
National Advisory Committee for INT at U of Washington

CONSTRAINING η/s vs. TEMPERATURE

G. DENICOL, A. MONNAI, B. SCHENKE, PHYS. REV. LETT. 116, 212301 (2016)



EXP DATA: PHOBOS COLL., B.B. BACK, ET AL., PHYS. REV. LETT. 94 (2005) 122303



CONCLUSIONS:

η/s IS NOT CONSTANT HADRONIC η/s IS LARGE QGP η/s CANNOT RISE QUICKLY

Thermalization of the Glasma

In largest classical-statistical real time lattice simulations to date:

- ◆ Discovery of a non-thermal fixed point in the 3+1-D real time evolution of an overoccupied QGP (the Glasma)
- ◆ This non-thermal turbulent attractor identifies the effective kinetic theory the system follows to equilibrium

Berges, Boguslavski, Schlichting, Venugopalan. PRD89 (2014), no. 7, 7074007 (91 cites)

Berges, Boguslavski, Schlichting, Venugopalan. PRD89 (2014), no.11, 7074007 (70 cites)

- ◆ Remarkable universality: Expanding self-interacting scalar fields (that Bose condense in the infrared) have identical dynamics with Glasma in wide momentum window

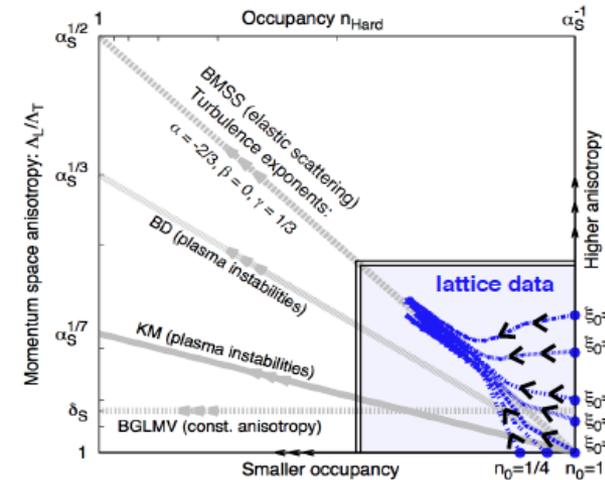
Berges, Boguslavski, Schlichting, Venugopalan, PRL 114 (2015) 061601, Editor's suggestion

- ◆ Very surprising from a kinetic theory perspective!

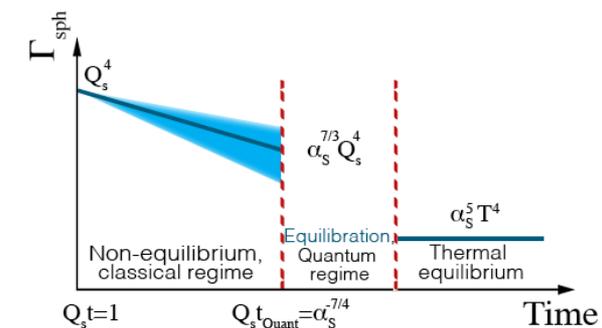
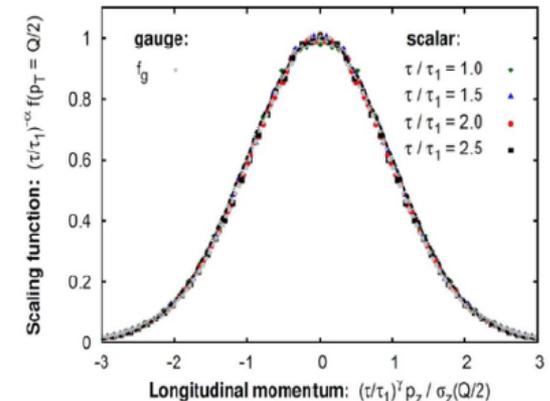
Berges, Boguslavski, Schlichting, Venugopalan, PRD92 (2015), no.9, 096006

- ◆ First computation of non-equilibrium sphaleron (topological) transitions in the Glasma
- essential for first principles computation of the Chiral Magnetic Effect

Mace, Schlichting, Venugopalan, PRD93 (2016), no.7, 074036



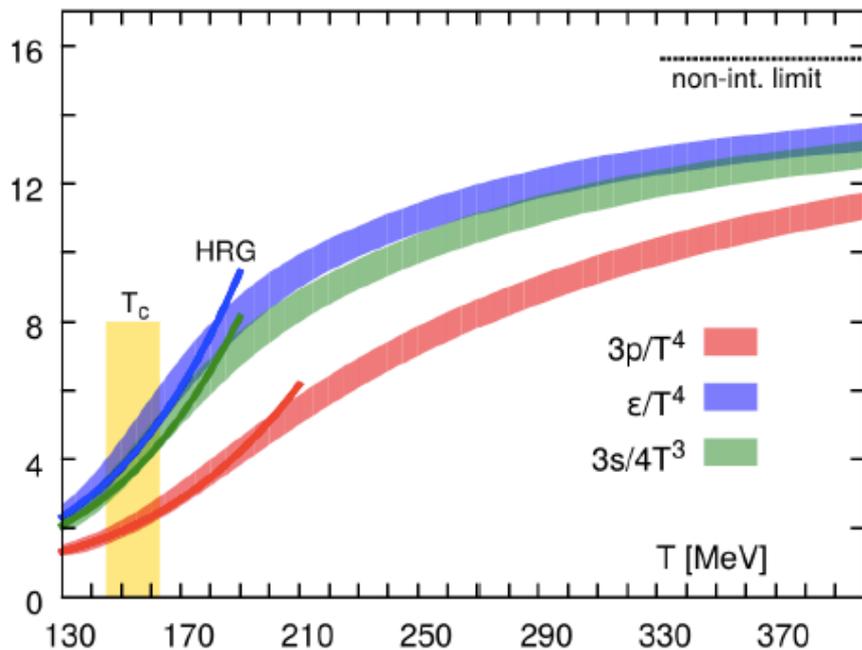
Universality of expanding scalar and gauge field distributions



Equation of state of (2+1)-flavor QCD

pressure, entropy & energy density

$$\mu_B/T = 0$$

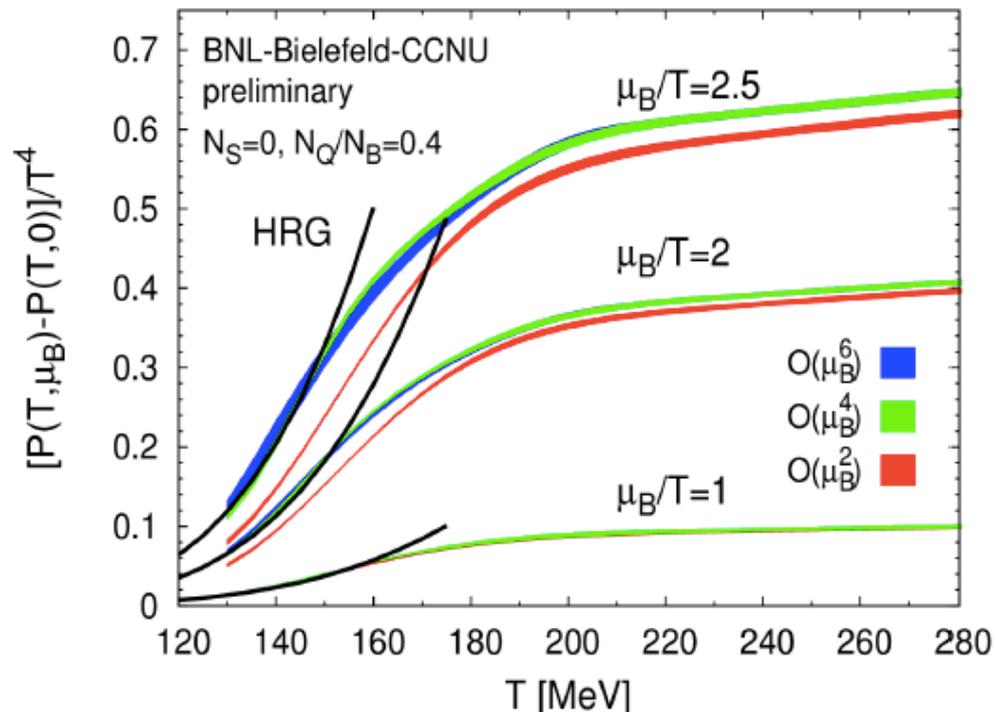


A. Bazavov et al. (hotQCD),
Phys. Rev. D90 (2014) 094503

EoS in (almost) the entire
range of energies covered
by BEST@RHIC

(ALCC project on Titan@ORNL
(S. Mukherjee et al.))

$$\mu_B/T > 0 \quad 6^{\text{th}} \text{ order Taylor series}$$



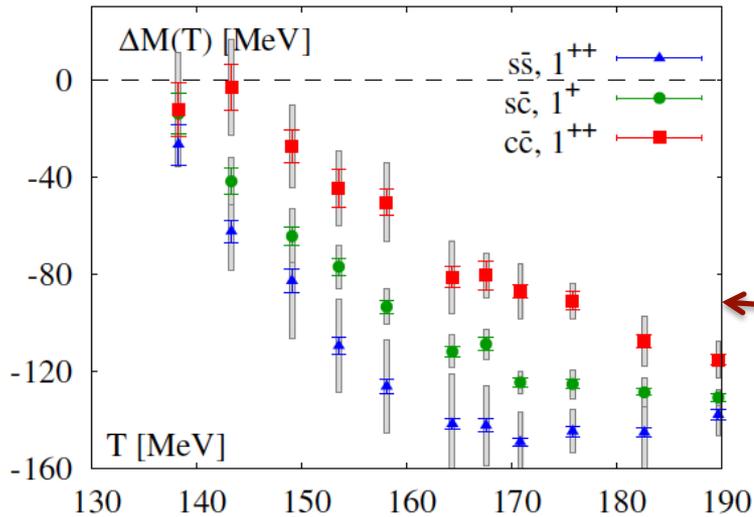
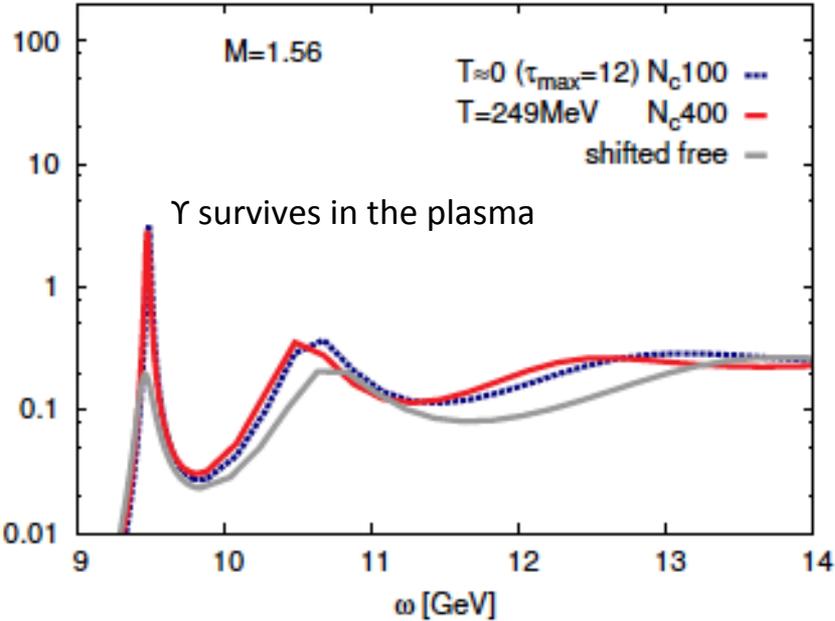
presented at Strange Quark Matter 2016
and Lattice 2016



The EoS is well controlled for $\mu_B/T \leq 2$
or equivalently $\sqrt{s_{NN}} \geq 20 \text{ GeV}$

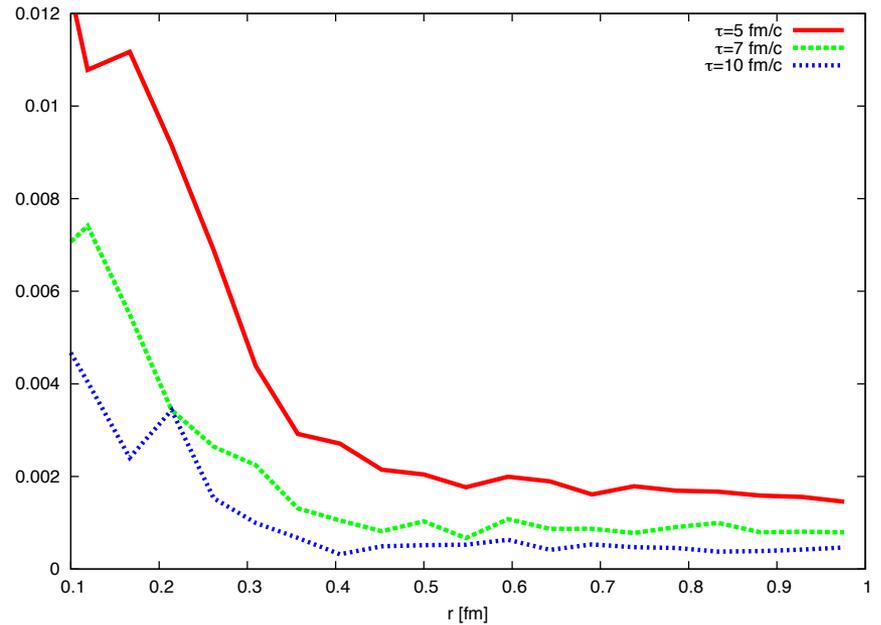
Quarkonium properties and production at $T > 0$

Bottomonium spectral function from lattice NRQCD
 S. Kim, PP, A. Rothkopf, PRD91 (2015) 054511



bb pairs in the hot medium simulated by Langevin dynamics remain correlated even in absence of bound states

\Rightarrow Υ can be formed again in the hot medium
 Petreczky, Young, arXiv:1606.08421 [nucl-th]

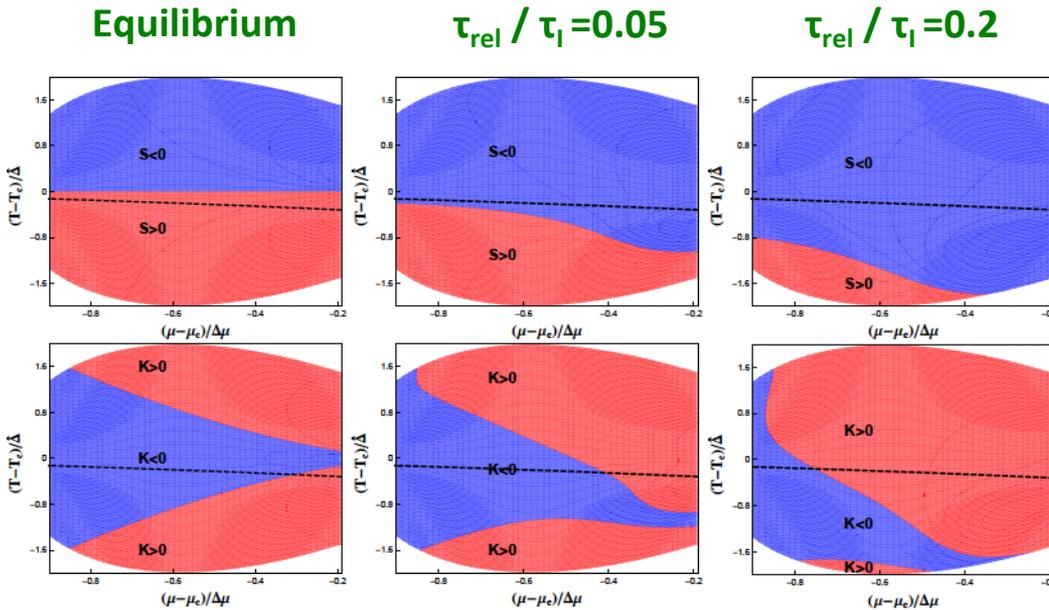


Study of spatial charmonium correlators on the lattice
 \Rightarrow Large shift in the screening mass of 1P charmonia
 \Rightarrow Sequential suppression pattern
 Bazavov, Karsch, Maezawa, Mukherjee, Petreczky,
 PRD 91 (2015) 054503

Memory effects of critical cumulants and the BES scan

◆ Novel formalism describes the non-equilibrium dynamics of non-Gaussian critical cumulants on crossover side of critical end point

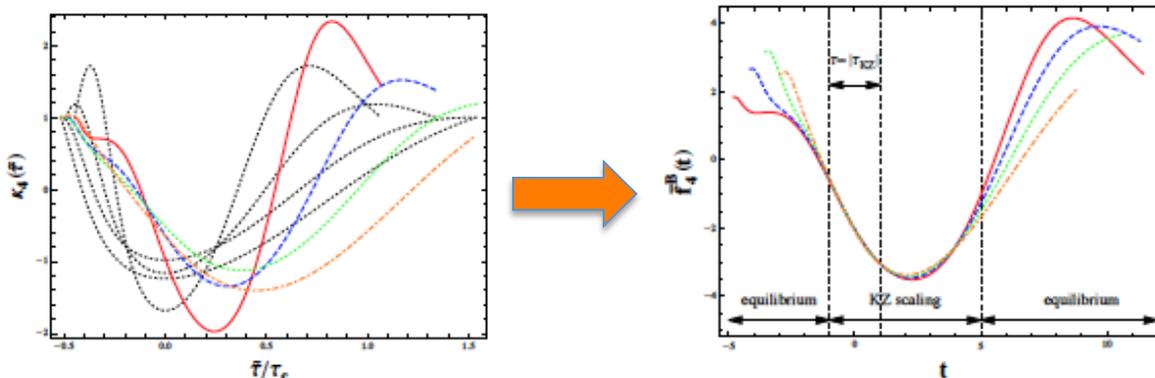
Mukherjee, Venugopalan, Yin, PRC92 (2015) no.3, 034912



Very significant memory effects!
May influence interpretation of non-monotonic behavior in BES

◆ New idea: Kibble-Zurek (KZ) mechanism requires that critical cumulants off-equilibrium *must* satisfy universal scaling in terms of emergent KZ scales

Mukherjee, Venugopalan, Yin arXiv:1605.09341

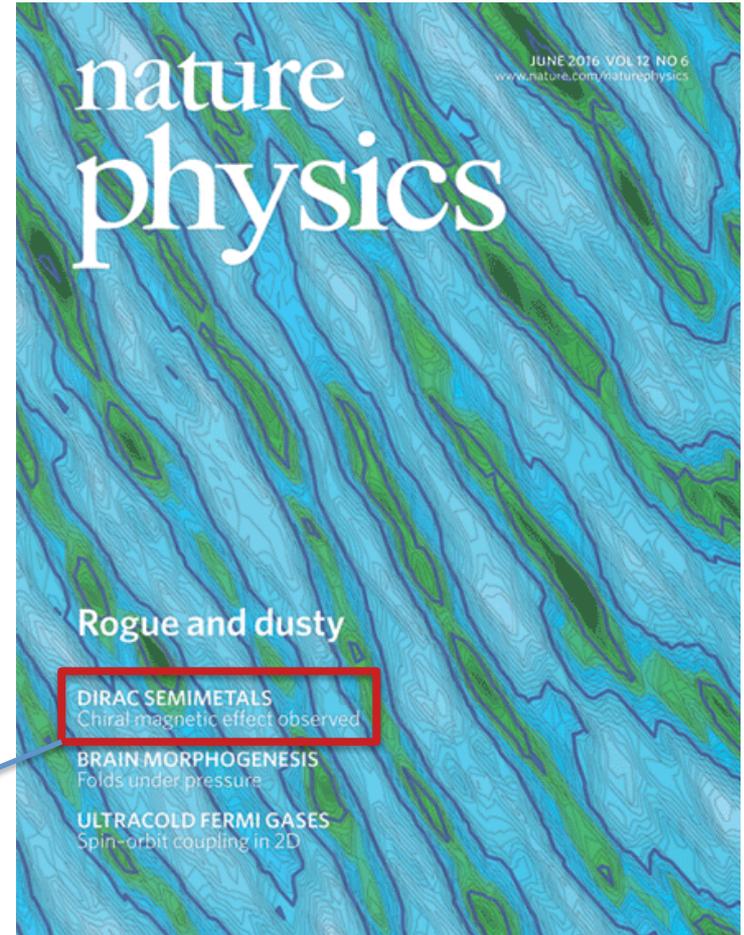
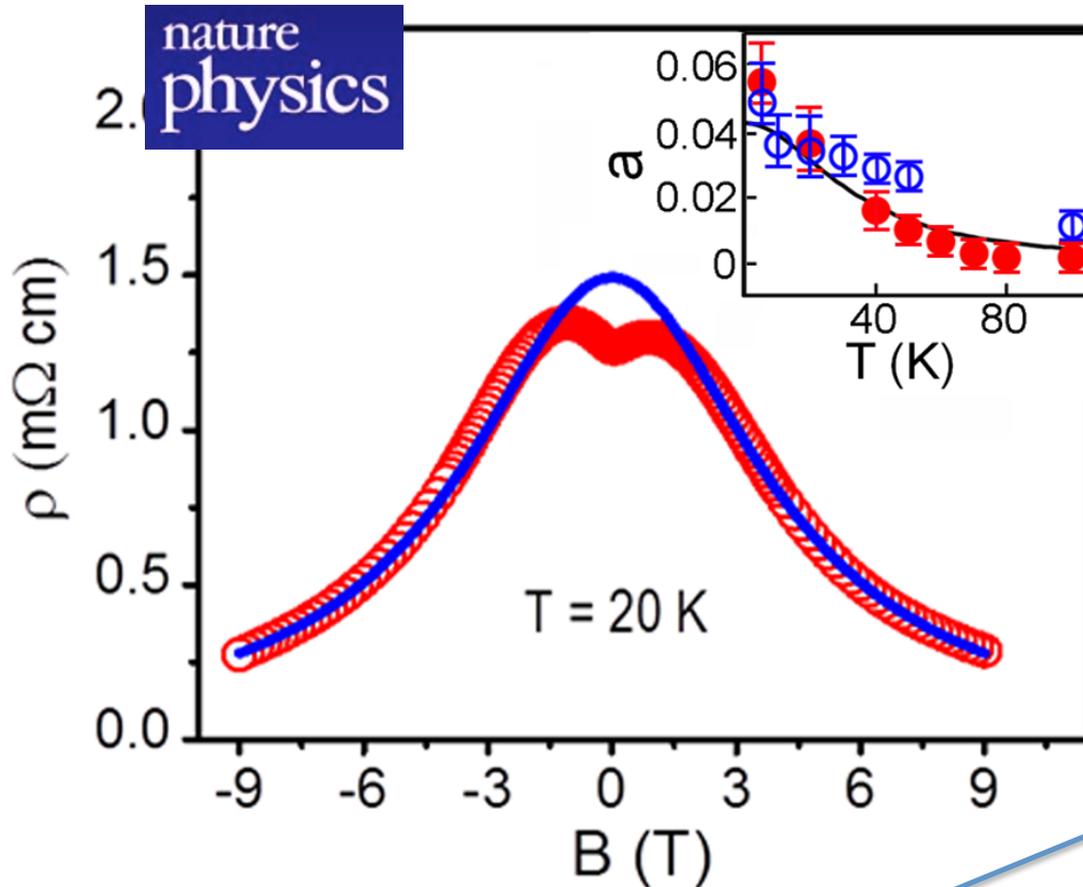


Chiral Magnetic Effect Generates Quantum Current

Separating left- and right-handed particles in a semi-metallic material produces anomalously high conductivity

February 8, 2016

Q.Li, D.Kharzeev et al,
Nature Physics **12**, 550 (2016)



Chiral magnetic effect observed

Onium production in p+p and p+A collisions

- ◆ First principles formalism combining CGC and NRQCD

Kang, Ma, Venugopalan, JHEP 1401 (2014) 056

- ◆ Successful application of CGC+NLO pQCD short distance framework with NRQCD to describe J/ψ production in p+p collisions

Ma, Venugopalan, PRL 113 (2014), no.19, 192301

- ◆ Same framework also describes J/ψ production in p+A collisions

Ma, Venugopalan, Zhang, PRD92 (2015) 071901

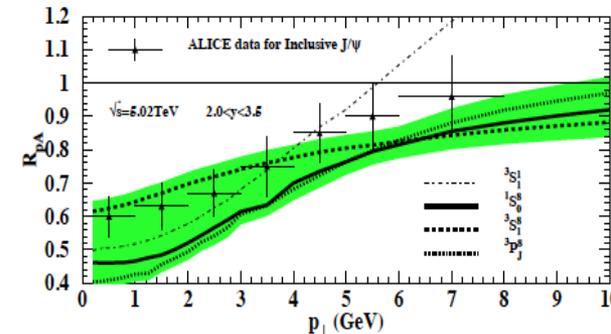
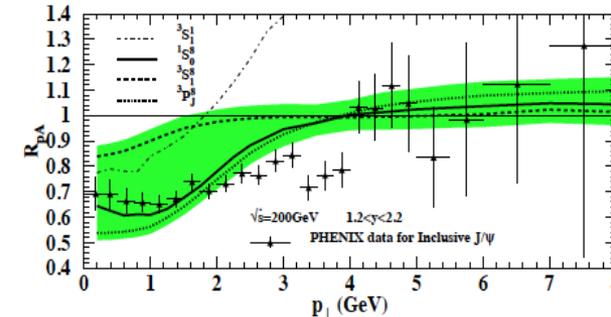
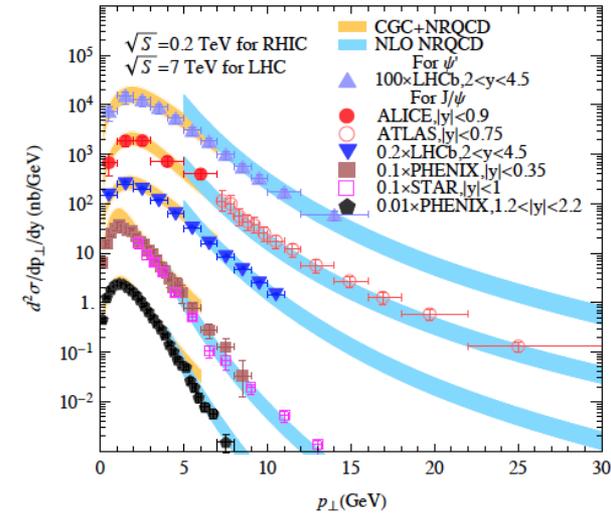
- ◆ This framework explains a puzzle in the pattern of suppression of ψ (2S) at the LHC

Ma, Venugopalan, Watanabe, Zhang, in preparation

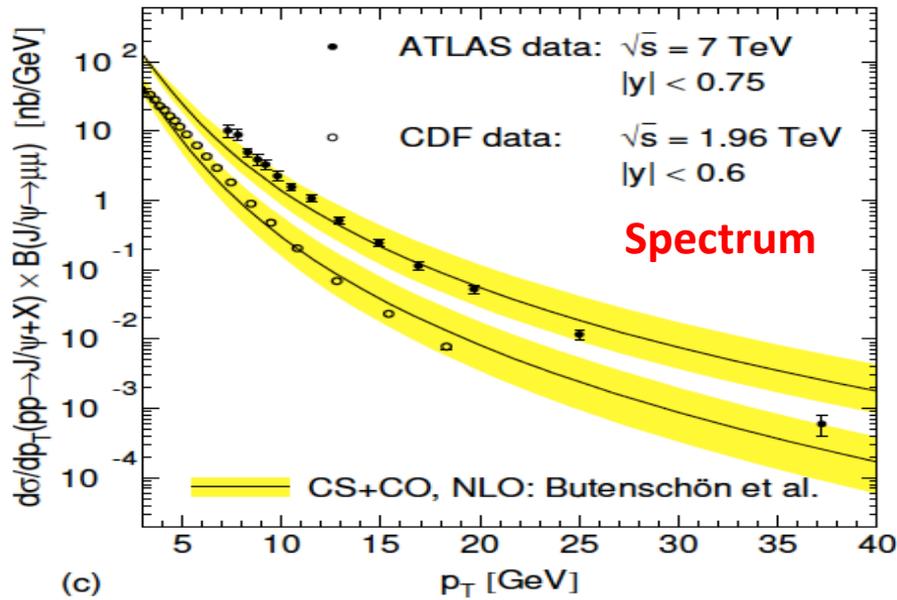
- ◆ Work in completion, applies this framework to inclusive photon production and photon-jet production

Garcia-Montero, Masters thesis (2016), Heidelberg U. (Venugopalan, co-supervisor)

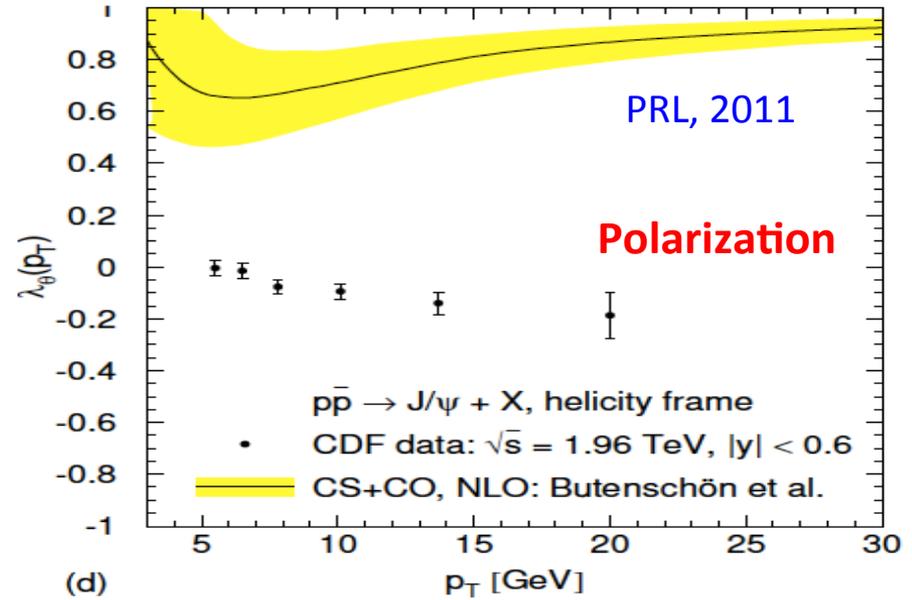
Benic, Fukushima, Garcia-Montero, Venugopalan, in preparation



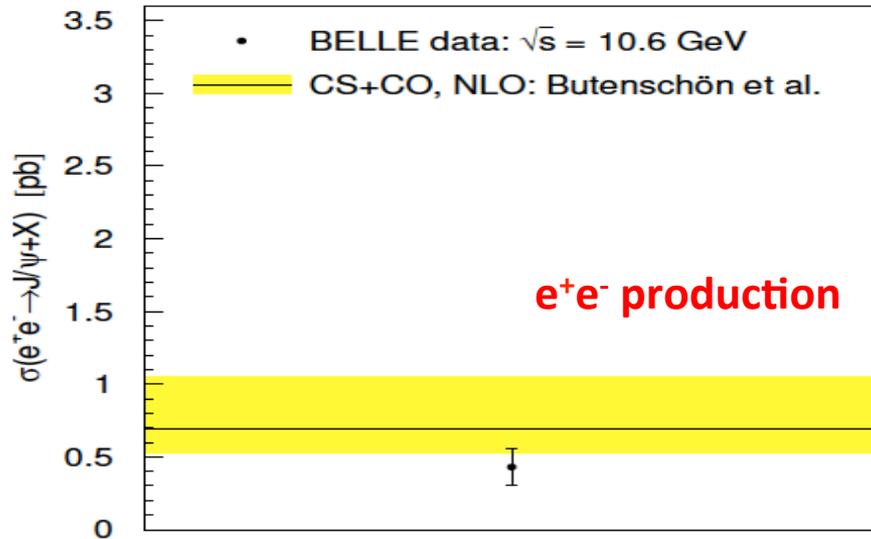
Difficulty with NRQCD – Butenschoen et al.



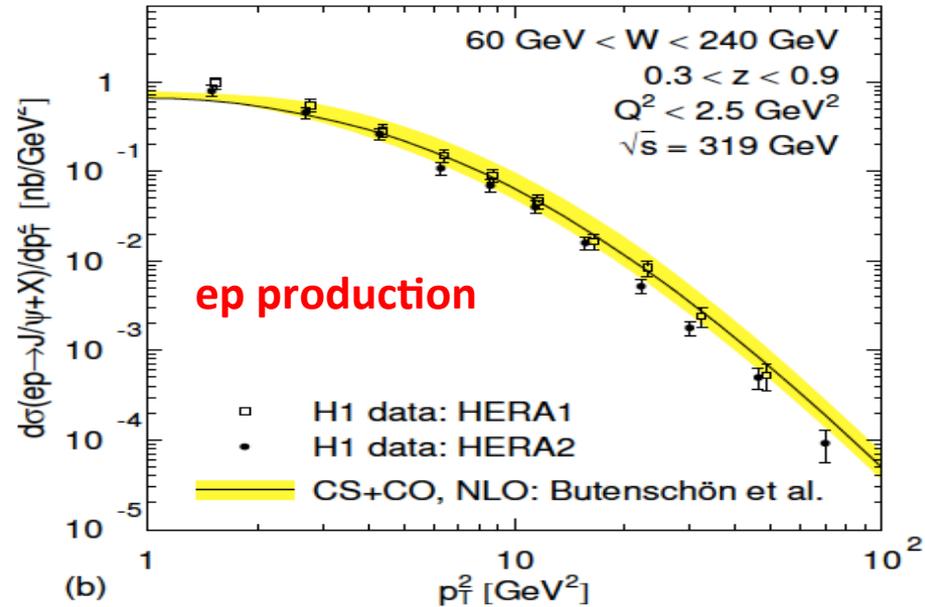
(c)



(d)

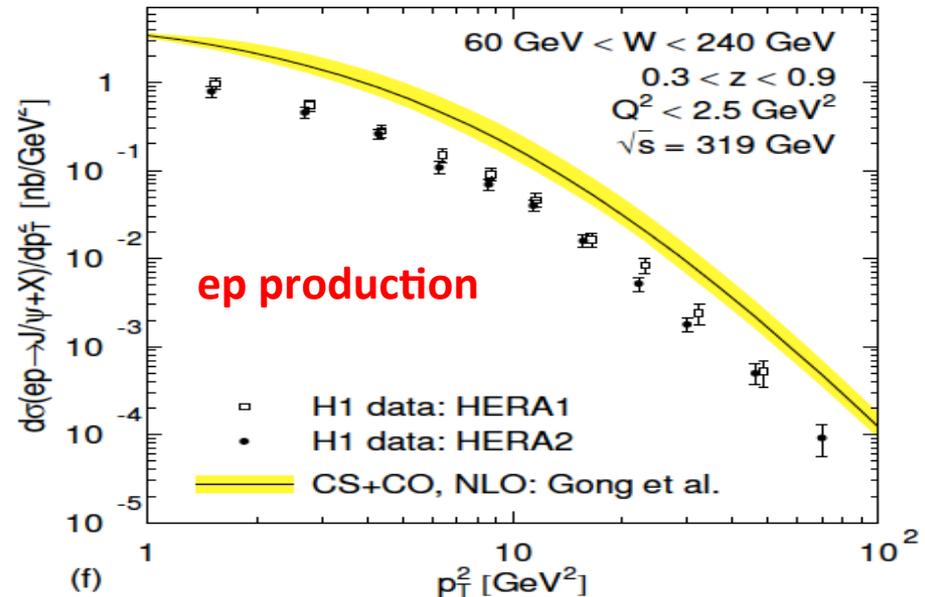
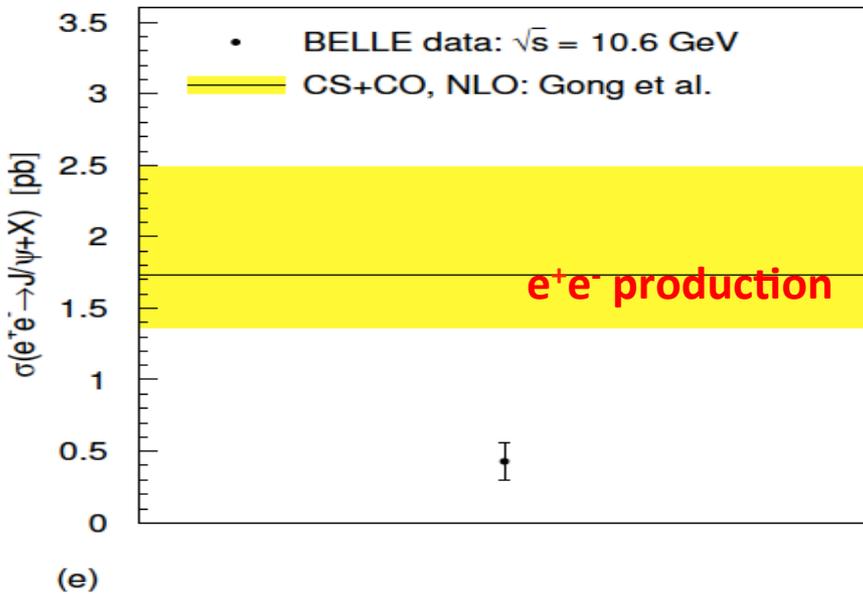
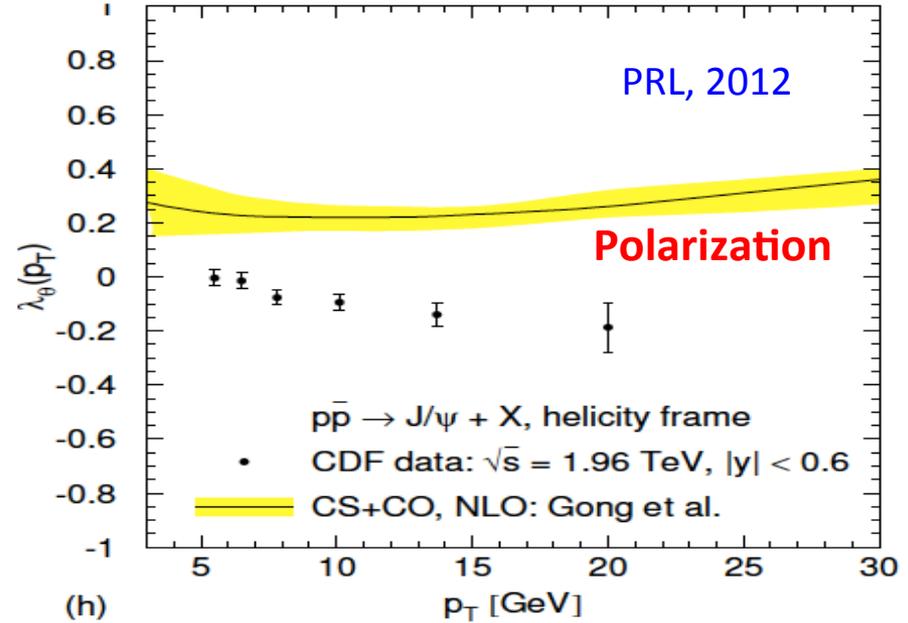
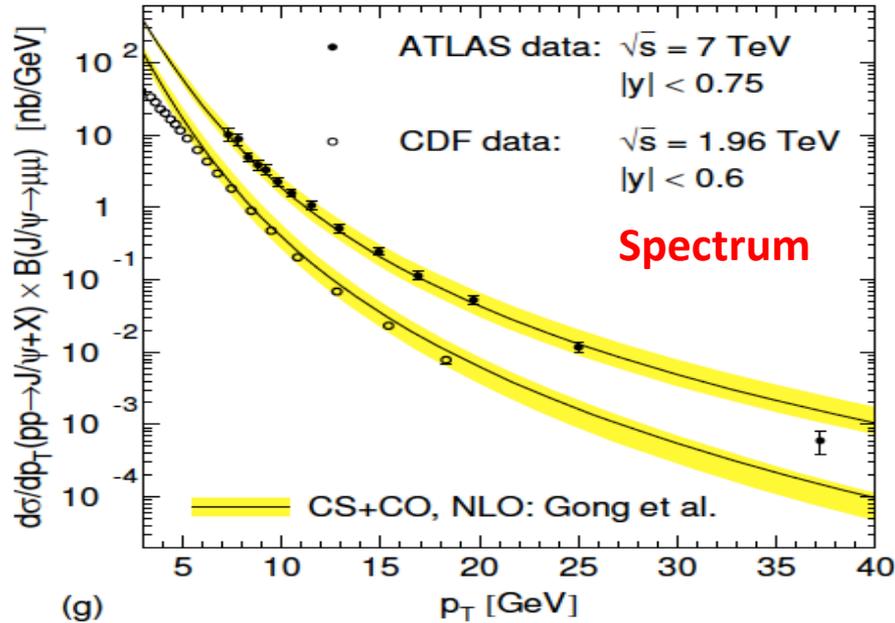


(a)

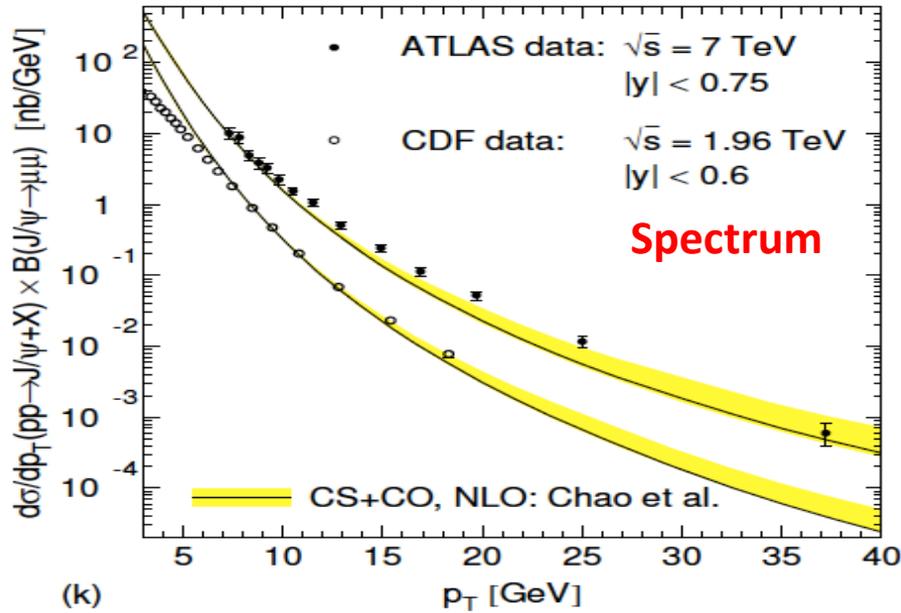


(b)

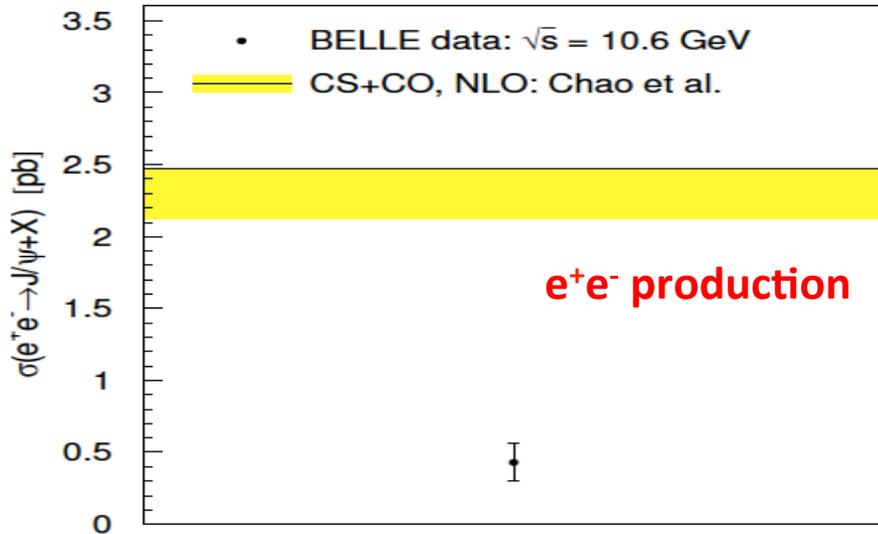
Difficulty with NRQCD – Gong et al.



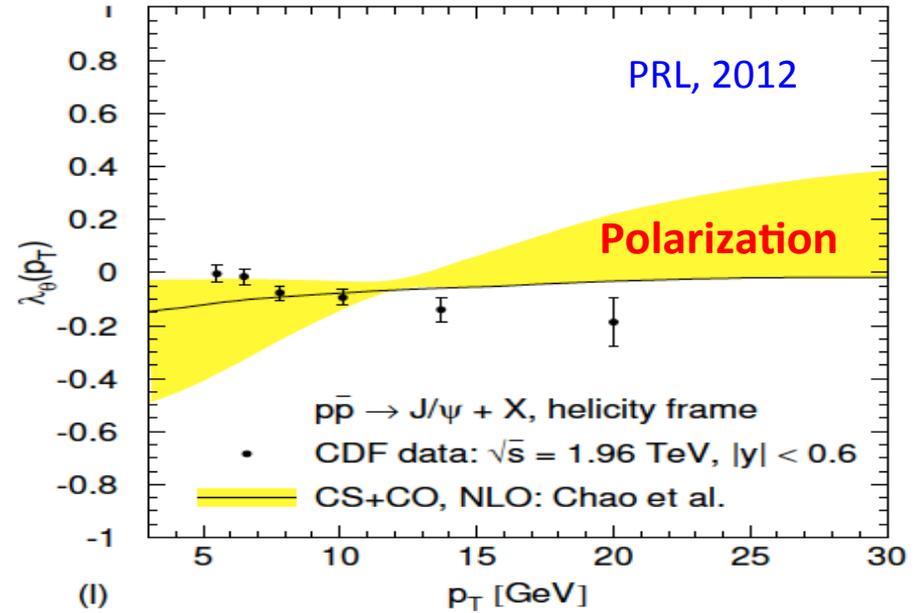
Difficulty with NRQCD – Chao et al.



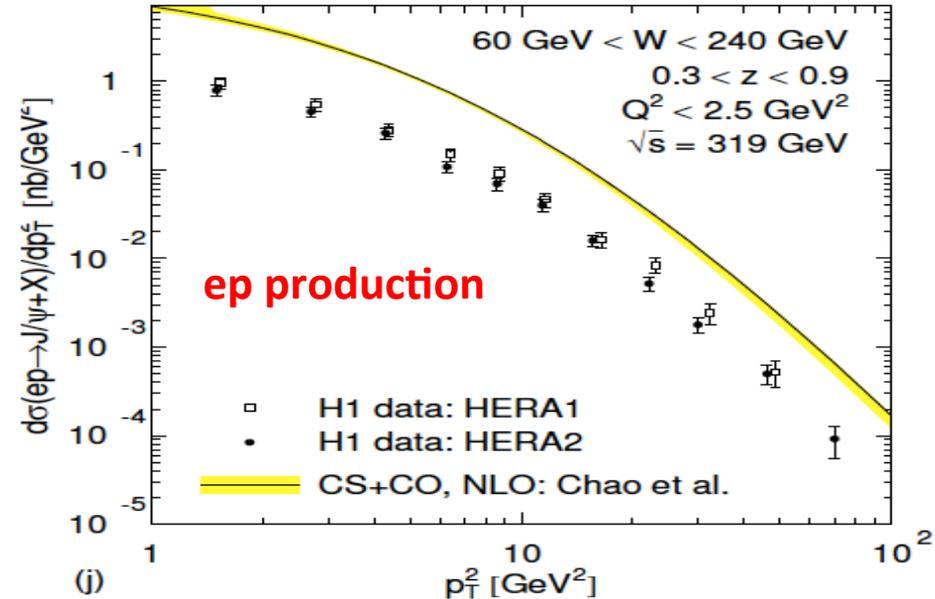
(k)



(i)



(l)

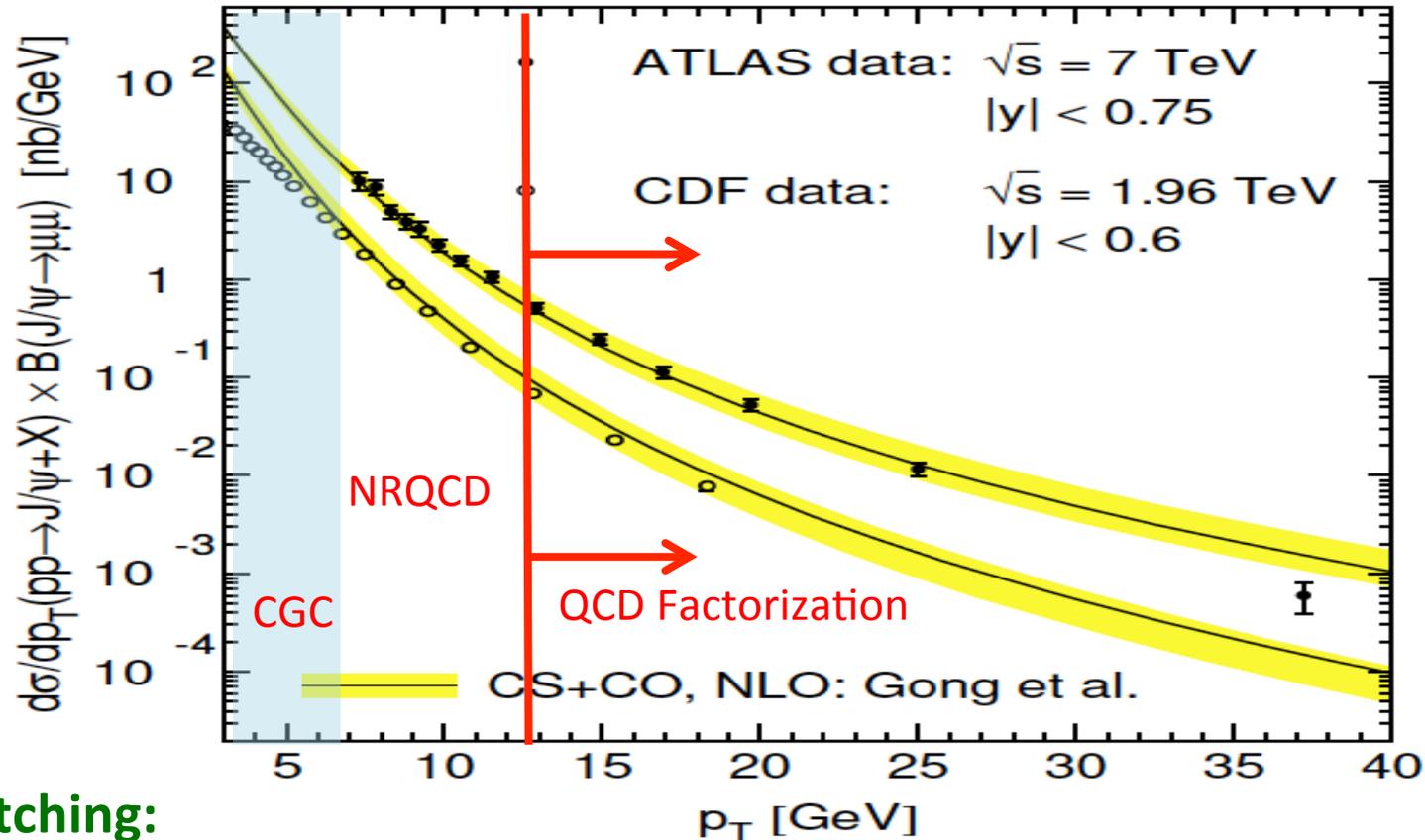


(j)

Matching between QCD and NRQCD

Kang, Ma, Qiu and Sterman, 2014

Expectation:



Matching:

$$E_P \frac{d\sigma_{A+B \rightarrow H+X}}{d^3P}(P, m_Q) \equiv E_P \frac{d\sigma_{A+B \rightarrow H+X}^{\text{QCD}}}{d^3P}(P, m_Q = 0) + E_P \frac{d\sigma_{A+B \rightarrow H+X}^{\text{NRQCD}}}{d^3P}(P, m_Q \neq 0) - E_P \frac{d\sigma_{A+B \rightarrow H+X}^{\text{QCD-Asym}}}{d^3P}(P, m_Q = 0)$$

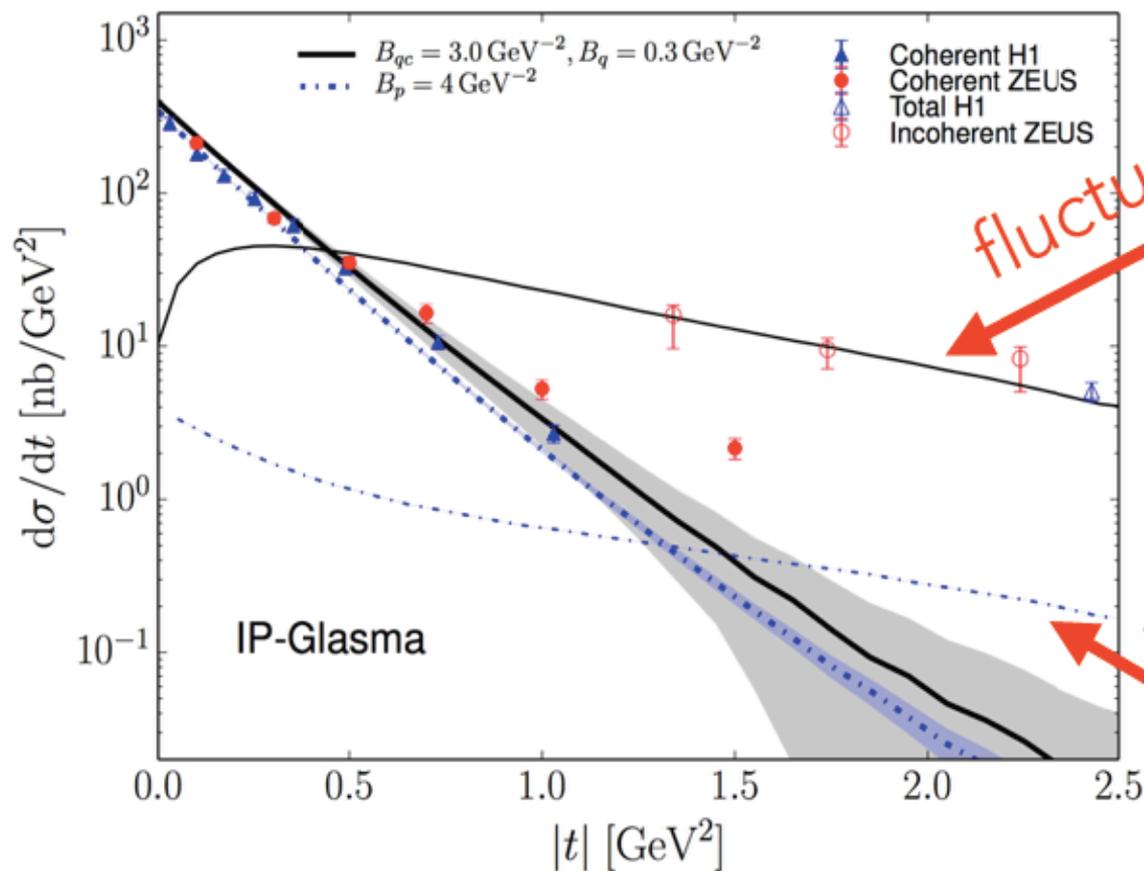
Mass effect + expanded P_T region ($P_T \gtrsim m_Q$)

MORE EVIDENCE FOR PROTON SHAPE FLUCTUATIONS



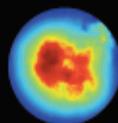
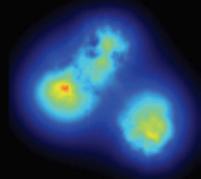
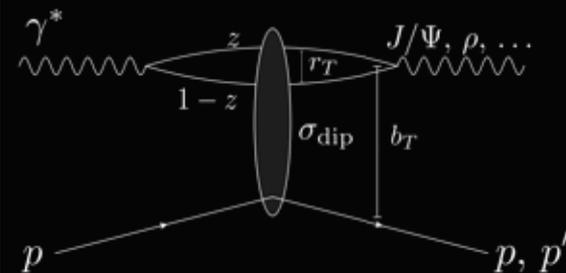
H. MÄNTYSAARI, B. SCHENKE, ARXIV:1603.04349, PRL IN PRINT

Exclusive diffractive J/Ψ production



fluctuating proton

round proton



Transverse spin: sign change & evolution

□ Siverson Effect: Hadron spin vs. parton motion

Prediction:

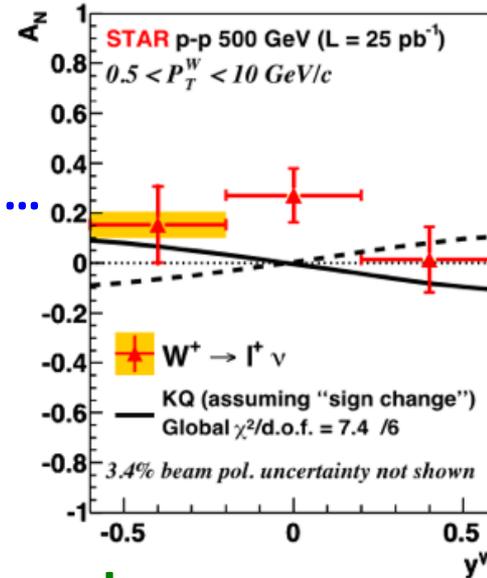
Sivers function from DIS

= - Sivers function from DY, W/Z, ...

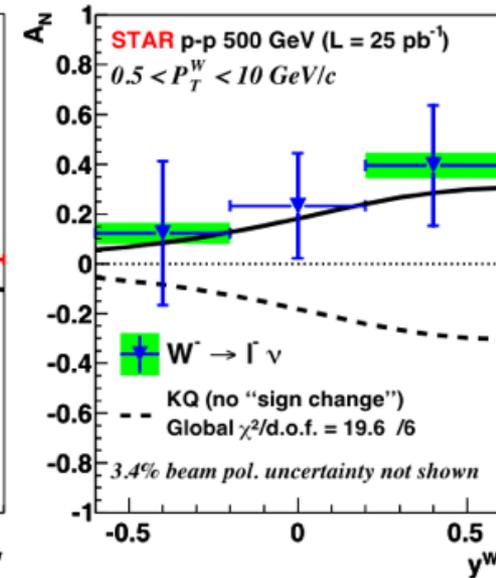
STAR Data:

Phys. Rev. Lett.
116, 132301 (2016)

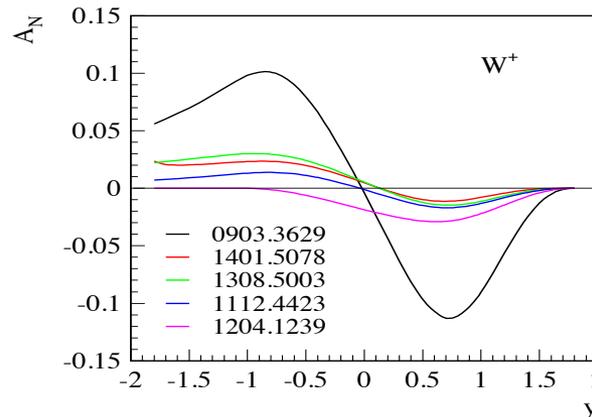
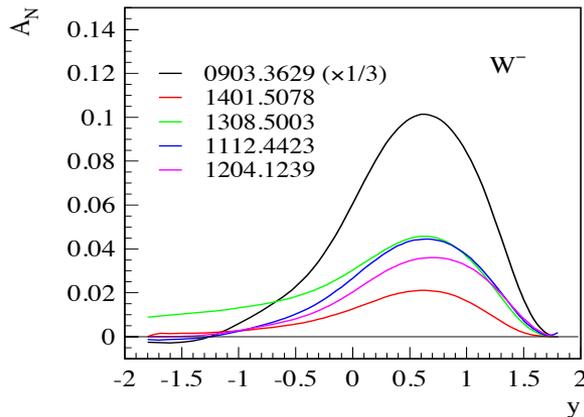
See talks by
Berndt & Elke



RHIC spin milestone



□ Theory improvement – scale dependence:



Role of
non-perturbative
input at large b?

Kang & Qiu

TMD collaboration proposal: Lattice, theory & Phenomenolog

RHIC is a unique facility to test this (W/Z – Run 17)!

Synergies with RBRC, HEP theory, SB, ...

□ RIKEN/BNL Research Center (RBRC):

Kharzeev: Head of RBRC Theory Group

Pisarski: Deputy Director of RBRC

- ✧ Active interaction and collaboration with RBRC Fellows and postdocs
- ✧ Active participation of RBRC review and planning
- ✧ Organizing and actively participating in RBRC Workshops

□ RBRC - HEP Lattice effort:

Qiu (NT), Ishikawa (RBRC), Izubuchi (RBRC & HEP), ...

BNL LDRD project: Exploring hadron structure with ab initio lattice QCD calculations and making predictions for eRHIC

□ Stony Brook University:

Kharzeev: Joint faculty appointment (~1/2 FTE)

Qiu: Brookhaven Professor

Venugopalan: Adjunct Professor

Ph.D. Students: Mace (Kharzeev&Venugopalan), Zhang (Qiu, Ph.D.2014)

Budget challenges

□ NTG+LGT Budget:

Short of ~ 3.5 FTEs – a long term problem in the Groups

Shortfall thus far made up by Physics Dept. and Operation funds

□ Staffing:

– Replacement of M. Stratmann – recommended by last S&T review

Critical to the spin and future EIC program

Asst Physicist/RBRC Fellow offer to Z.-B. Kang (LANL, by 1Pd+RBRC)

– Departure of L. McLerran:

Major loss to the theory activities (RHIC/HI, CGC, ...), How to replace him?

□ Short-term issues:

Other than those supported by ECA and LDRD, two groups have only one postdoc for each group – Need young postdocs!

□ Long-term solutions:

Active on-going discussion for a long-term orderly solution, while maintaining the Groups' record of excellence

DOE Topical Theory Collaboration

DOE Announcement:

The Office of Nuclear Physics (NP), on the basis of a peer review, has selected the following Topical Collaborations (to start in FY 2016) for funding recommendation:

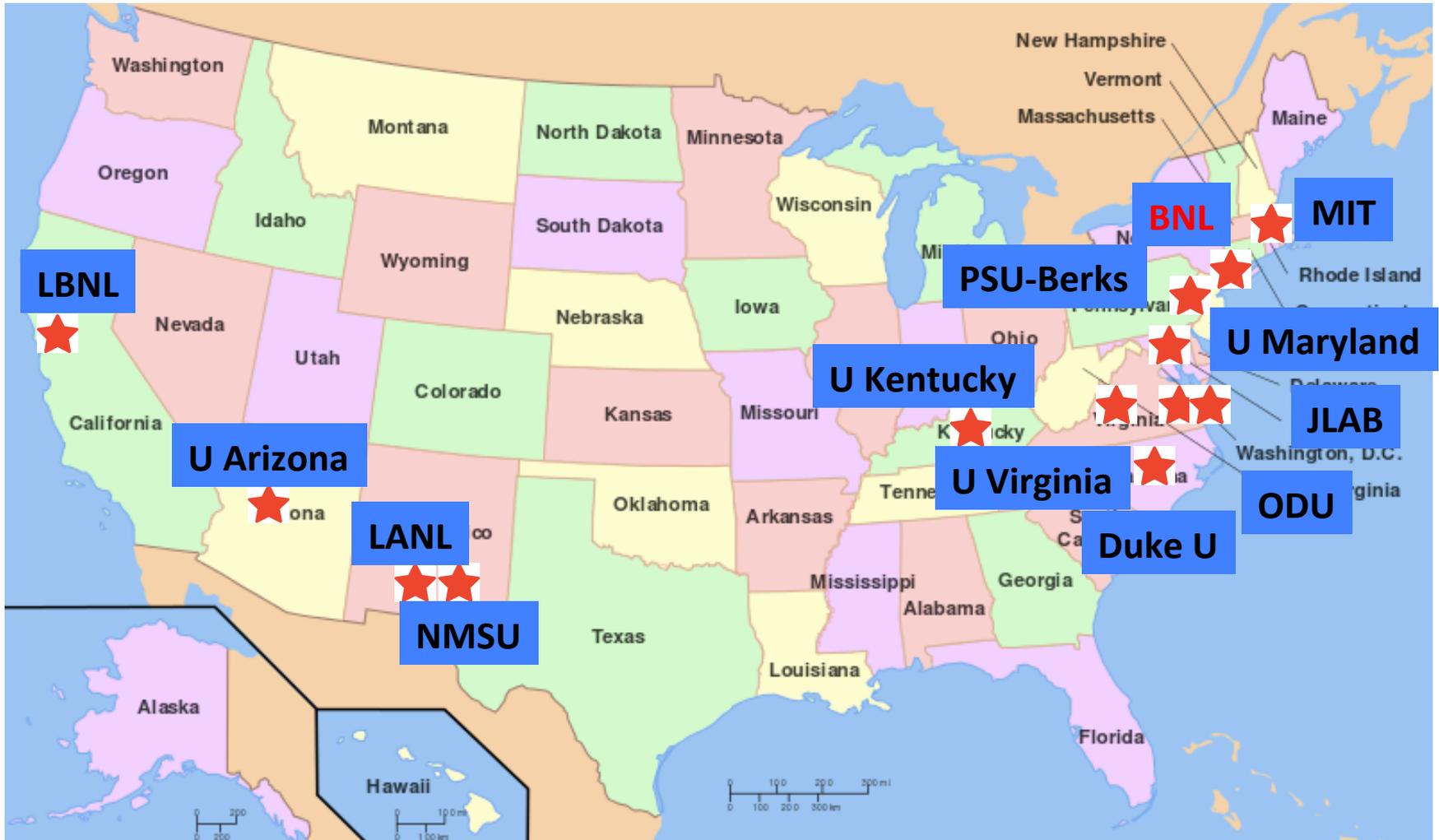
- **Coordinated Theoretical Approach to Transverse Momentum Dependent Hadron Structure in QCD (TMD Collaboration)**
Principal Investigator/Project Director: Jianwei Qiu
Lead Institution: Brookhaven National Laboratory
- **Nuclear Theory for Double-Beta Decay and Fundamental Symmetries (DBD Collaboration)**
Principal Investigator/Project Director: Jonathan Engel
Lead Institution: University of North Carolina at Chapel Hill
- **Beam Energy Scan Theory Collaboration (BEST Collaboration)**
Principal Investigator/Project Director: Swagato Mukherjee
Lead Institution: Brookhaven National Laboratory

BNL host 2 of the 3 DOE Topical Nuclear Theory Collaborations

TMD Topical Theory Collaboration

□ The Collaboration:

Has 3 National Labs + 10 Universities

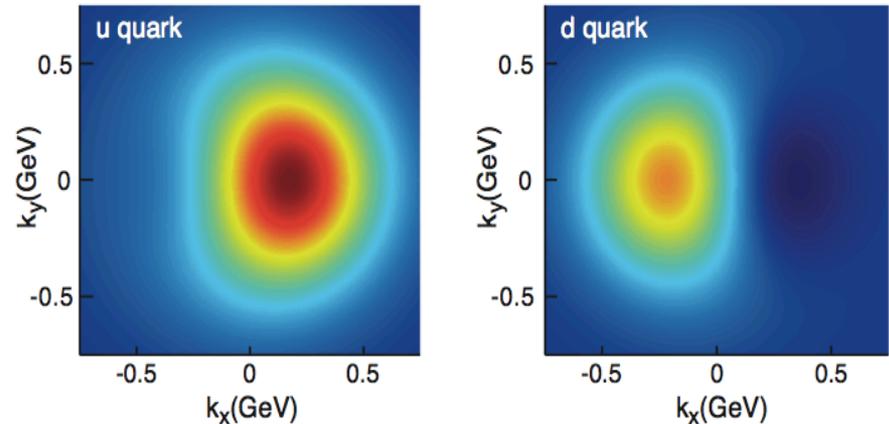
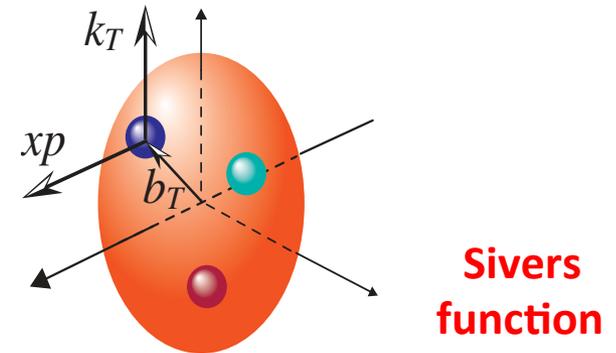


TMD Topical Theory Collaboration

□ Objectives/Deliverables – 3D Confined Motion:



- ✧ Matching x-section to parton motion
 - QCD factorization
- ✧ Parton motion vs. probing scale
 - QCD quantum evolution
 - RHIC Run17 – W program
- ✧ Lattice QCD calculation of TMDs
 - QCD 1st principle prediction?
- ✧ Fast software to extract TMDs
 - Service to community
- ✧ Training + career opportunities
 - 2 bridged faculty positions
 - 6 postdocs
 - 5 students
 - 3 Topical working groups, ...



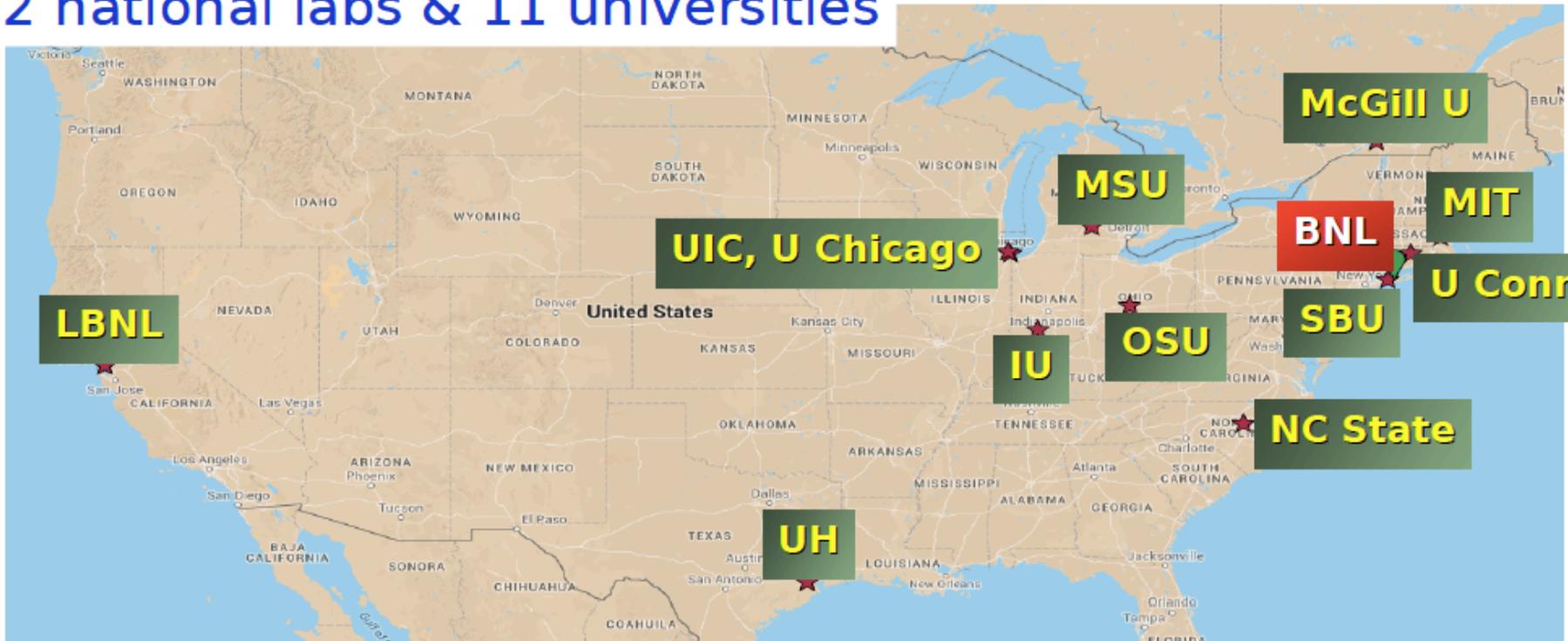
Density distribution of an unpolarized quark in a proton moving in z direction and polarized in y-direction

BEST Topical Theory Collaboration

□ Beam Energy Scan Theory Collaboration:



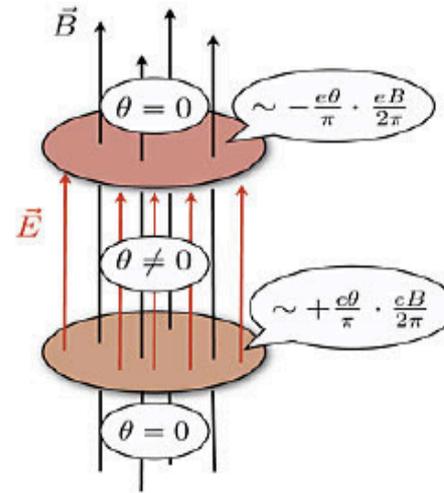
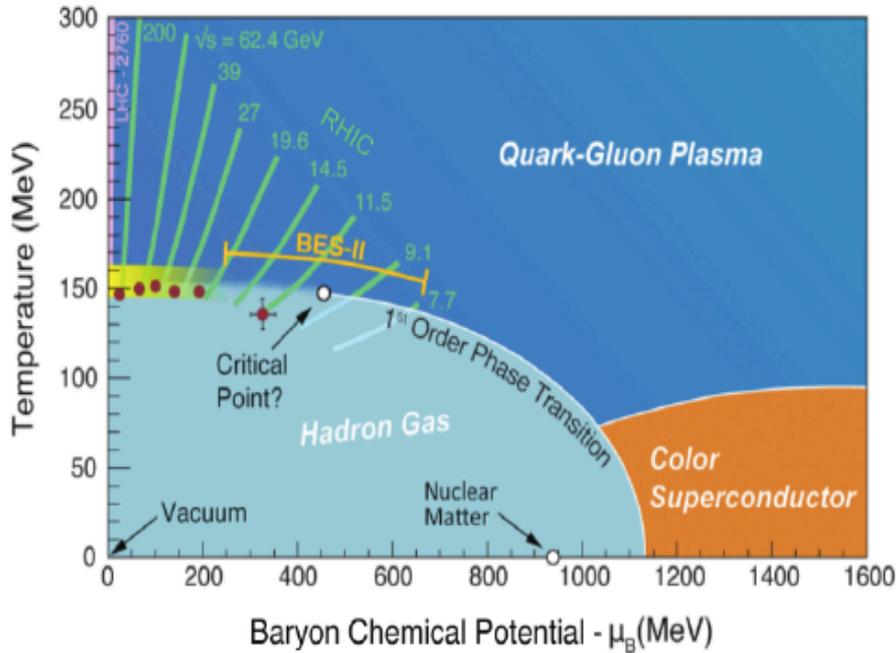
2 national labs & 11 universities



funded by: US Department of Energy, Office of Nuclear Physics

2016-2020

BEST Topical Theory Collaboration

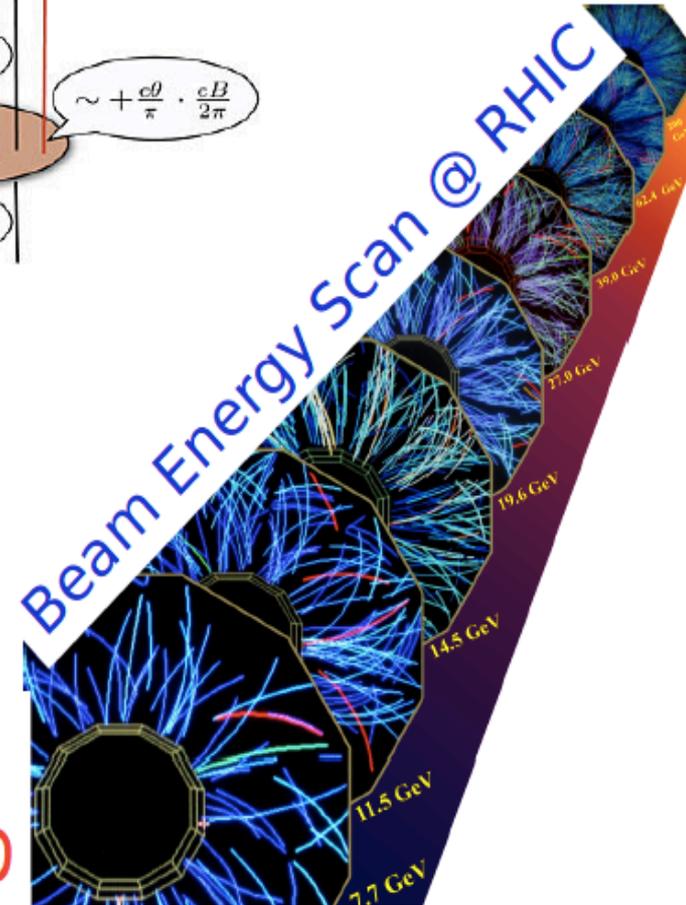


BEST
COLLABORATION

phases & properties of baryon-rich strong-interaction matter

chiral-anomaly induced effects in QGP

BES II:
2019-2020



BEST Topical Theory Collaboration



- /** discover, or put constraints on the existence, of a critical point in the QCD phase diagram
- /** locate the onset of chiral symmetry restoration by observing correlations related to anomalous hydrodynamic effects in quark gluon plasma
- /** construct and provide a theoretical framework for interpreting the results from the BES @ RHIC
 - hot-dense lattice QCD
 - initial state models
 - state-of-the-art hydrodynamic codes incorporating dissipation, hydrodynamic & critical fluctuations, effects of the chiral anomaly
 - hadronic models of the final state of a heavy ion collision

Summary

- ❑ Nuclear theory research at BNL are very active and productive
- ❑ It closely interacts with RHIC experimental activities
- ❑ Good synergies with RBRC, HEP, ...
- ❑ Having 2 of 3 Topical Theory Collaborations at BNL will make BNL the center of nuclear theory activities for at least next 5 years
- ❑ Challenges:
 - ✧ Personnel change
 - McLerran's departure, major loss, hard to replace
 - ✧ Budget
 - More than \$1M in deficit, develop workable plan between DOE&BNL
 - ✧ Future – EIC era
 - Transition from RHIC/HI to EIC physics, staffing, ...

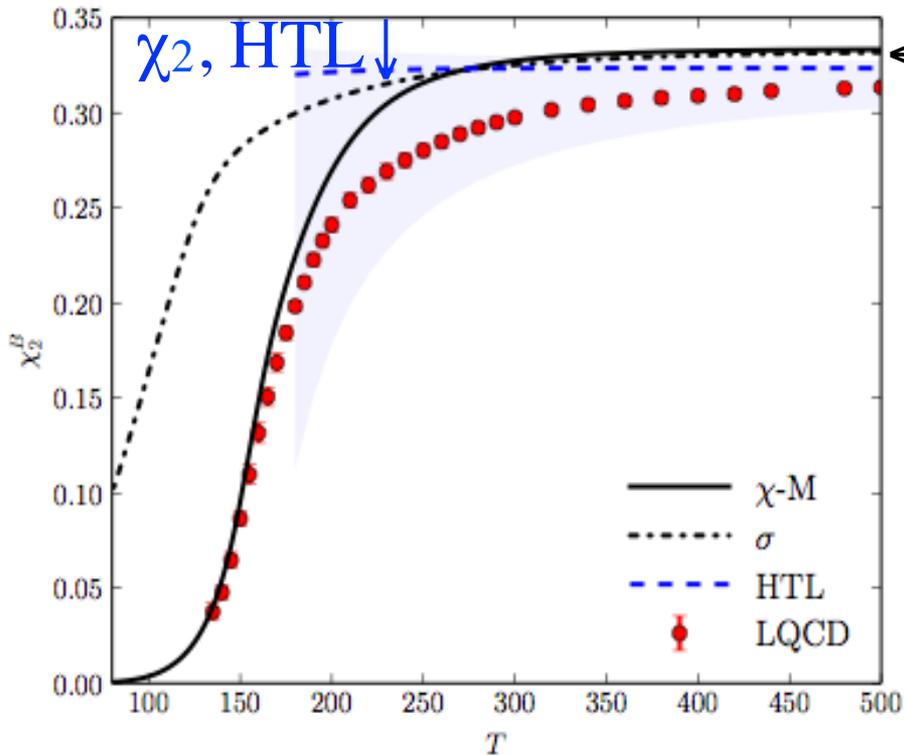
Thank you!

Back-up slides

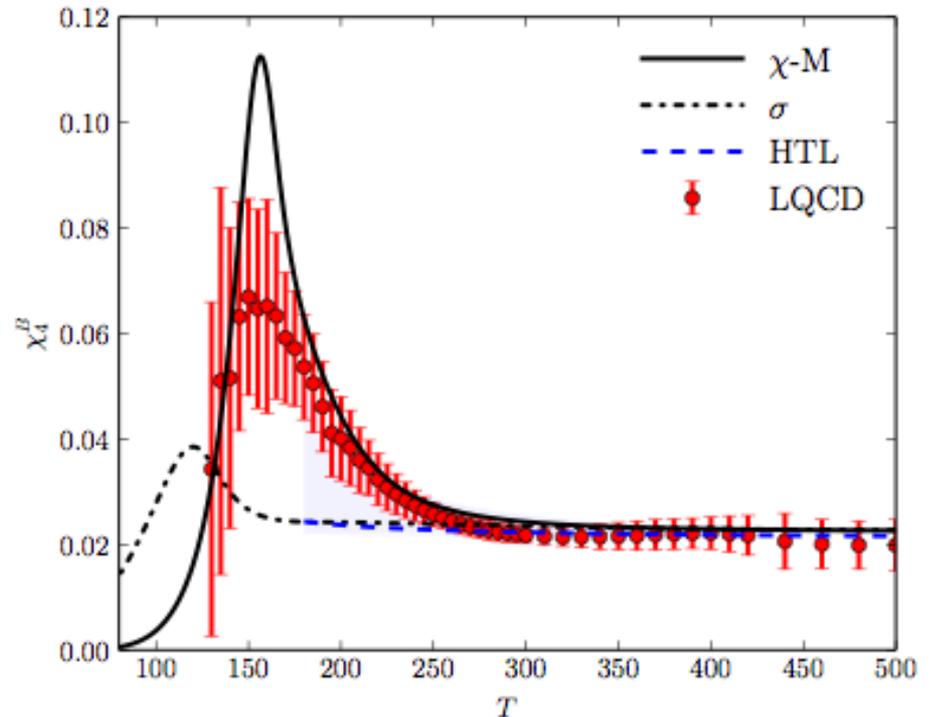
Chiral matrix model, baryon susceptibilities

Matrix model for pure glue + linear sigma model:

$$\chi_n^B(T) = T^{n-4} \left. \frac{\partial^n}{\partial \mu_B^n} p(T, \mu_B) \right|_{\mu_B=0}$$



χ_2, model



Two chiral phase transitions from tetraquarks

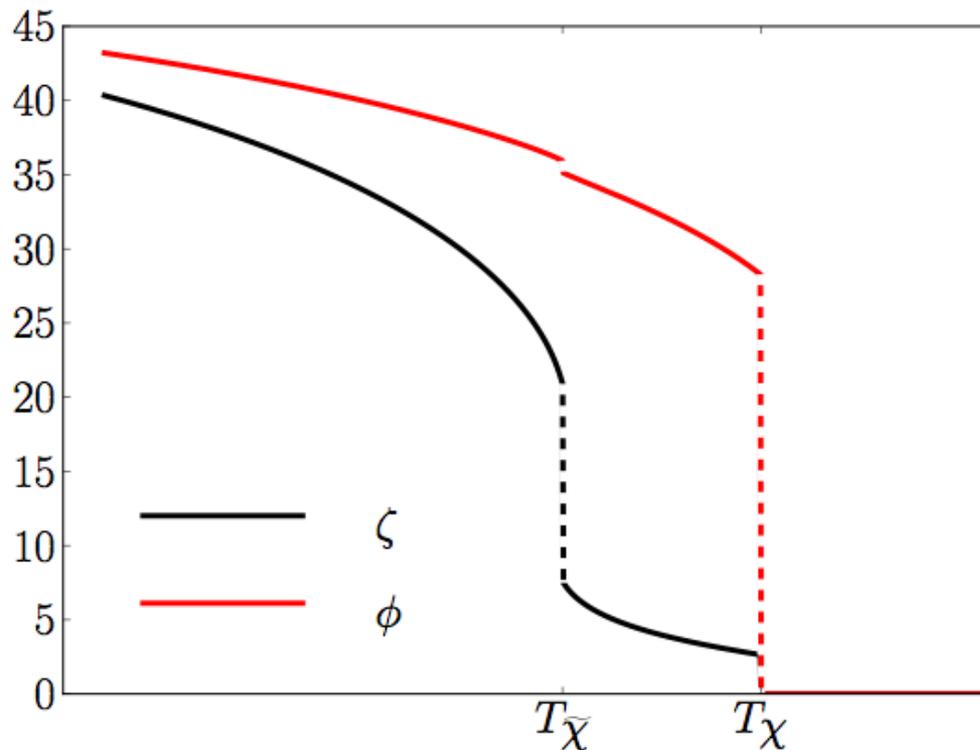
For three light flavors, the tetraquark ζ and usual chiral ϕ transform in the *same* representation of $SU(3)_L \times SU(3)_R$.

Hence tetraquarks *must* be included to understand the QCD phase diagram.

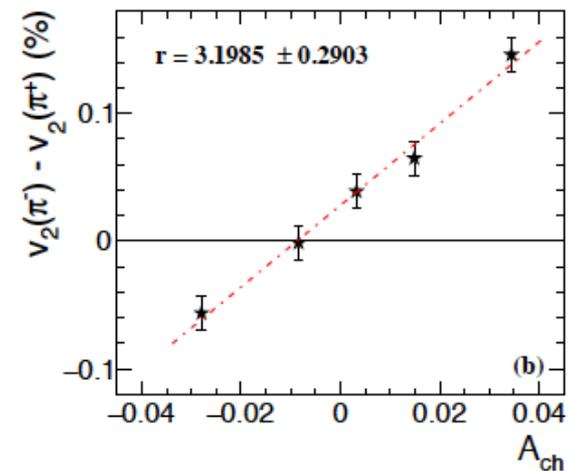
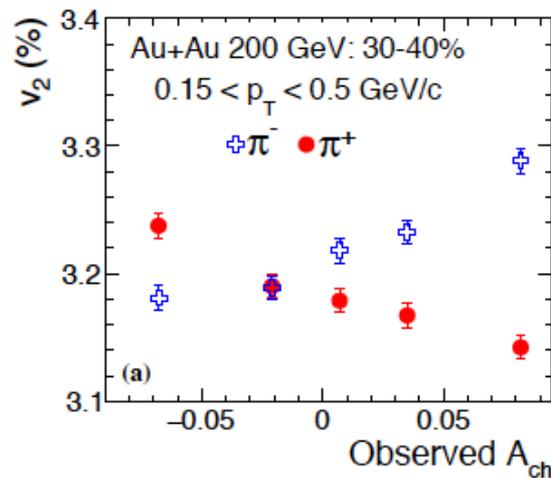
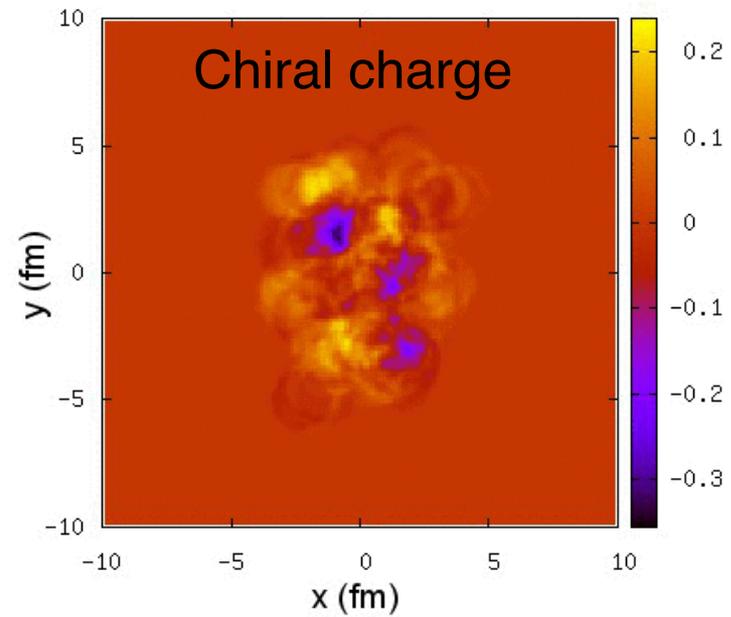
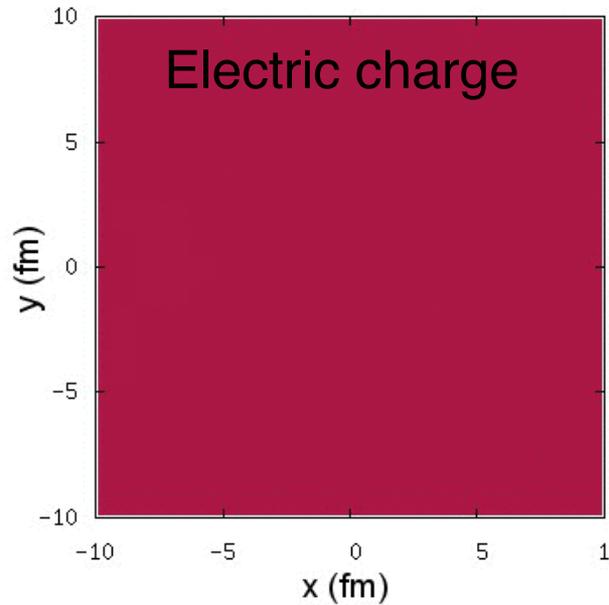
For very light quarks, *may* get two chiral phase transitions.

V. Skokov & RDP:

1606.04111



Chiral magneto-hydrodynamics



Y.Hirono, T.Hirano, D.Kharzeev,
(3+1) ideal CMHD

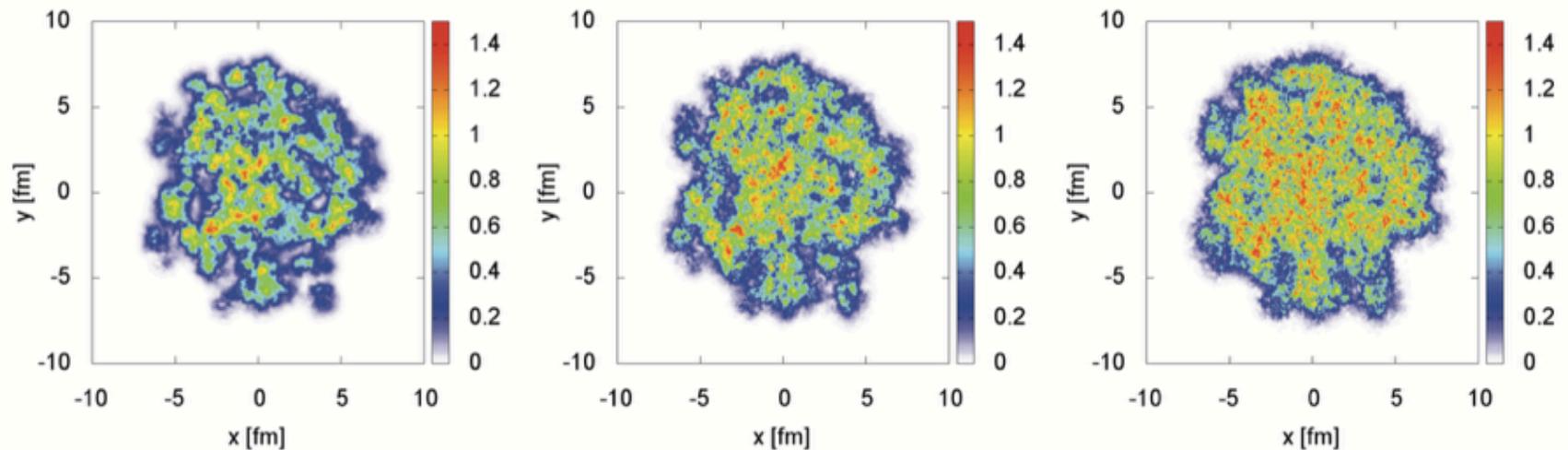
BEST Theory Collaboration

3D GLASMA INITIAL STATE

B. SCHENKE, S. SCHLICHTING, ARXIV:1605.07158, SUBMITTED TO PRC

EXISTING 3D INITIAL STATE MODELS ARE VERY SIMPLISTIC
NOW DO A FIRST PRINCIPLES 3D CALCULATION USING
CLASSICAL YANG-MILLS + QCD JIMWLK EVOLUTION

GLUON FIELDS IN A NUCLEUS AT DIFFERENT x :



$$Y = -2.4 \quad (x \approx 2 \times 10^{-3})$$

$$Y = 0 \quad (x \approx 2 \times 10^{-4})$$

$$Y = 2.4 \quad (x \approx 1.6 \times 10^{-5})$$

CORRELATIONS FROM THE INITIAL STATE

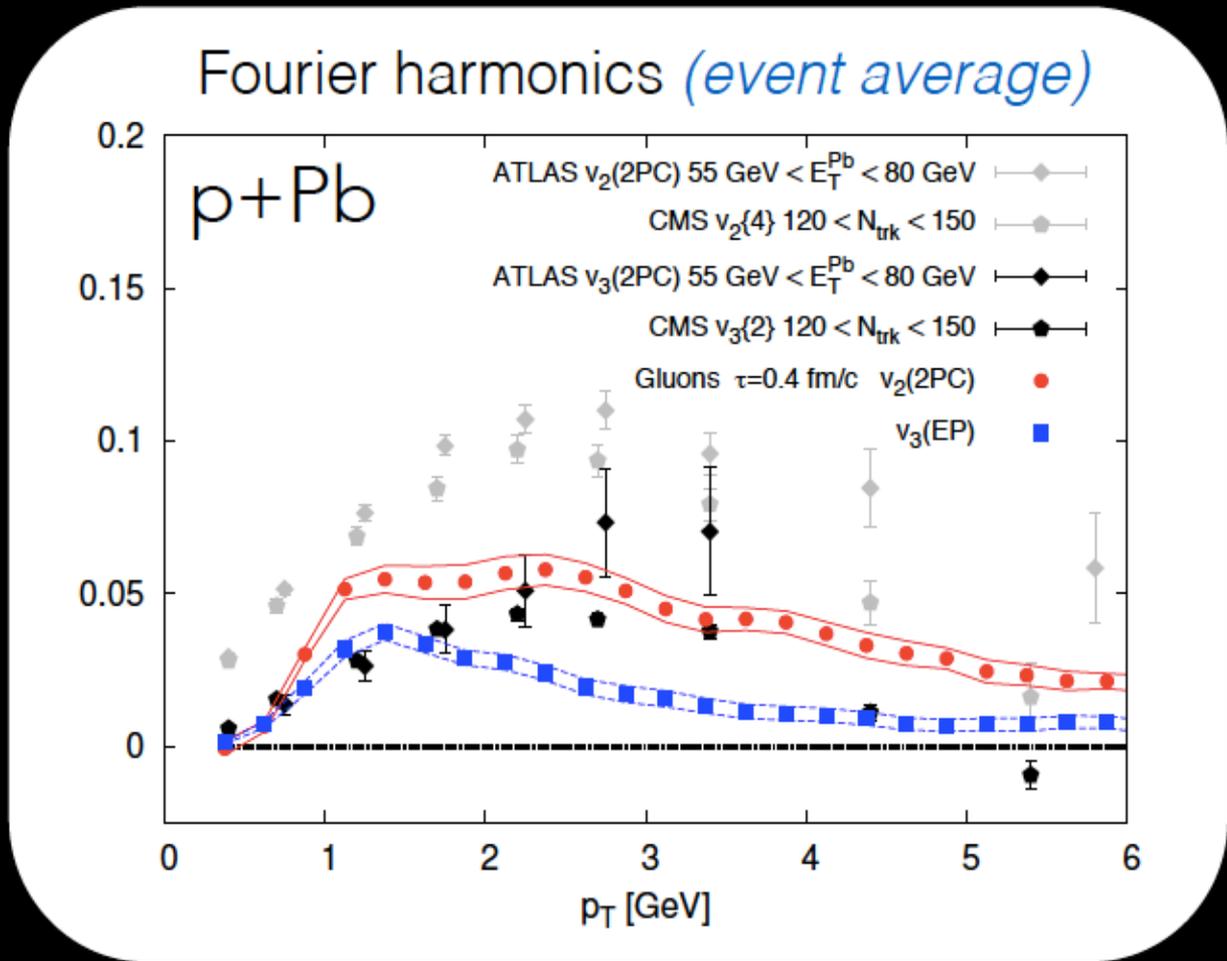
SCHENKE, SCHLICHTING, VENUGOPALAN, PHYS. LETT. B747, 76-82 (2015)

$\tau = 0.4 \text{ fm}/c$

gluons

data to guide the eye

v_2, v_3



Odd harmonics generated by pre-equilibrium dynamics

HADRONIZING THE GLUONS

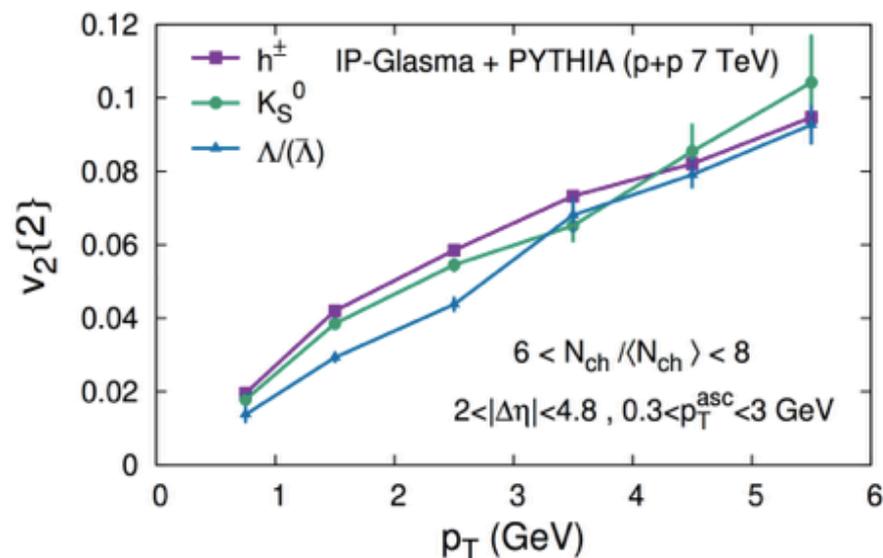
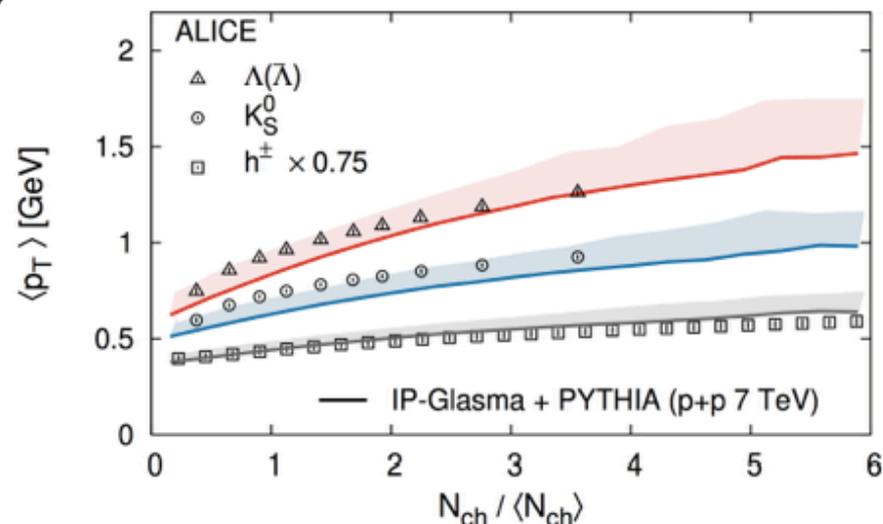
SCHENKE, SCHLICHTING, TRIBEDY, VENUGOPALAN, IN ARXIV:1607.01711

Do we see mass splitting
without hydro?

Classical Yang-Mills
coupled to PYTHIA's
Lund fragmentation

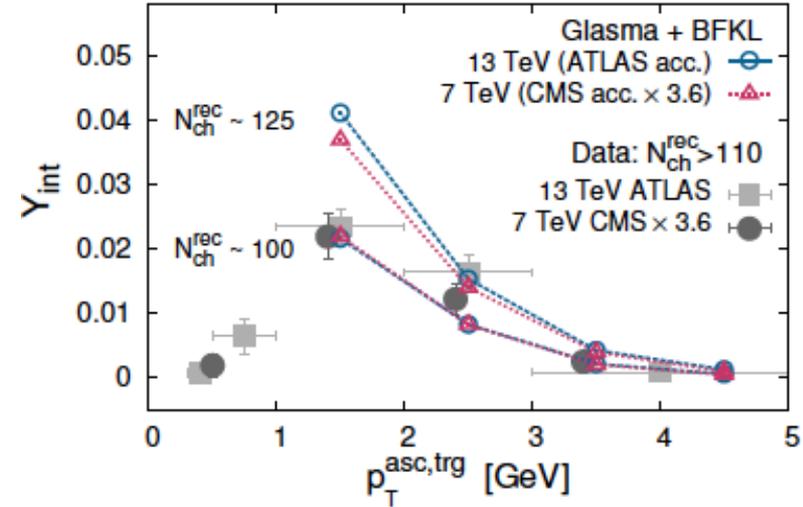
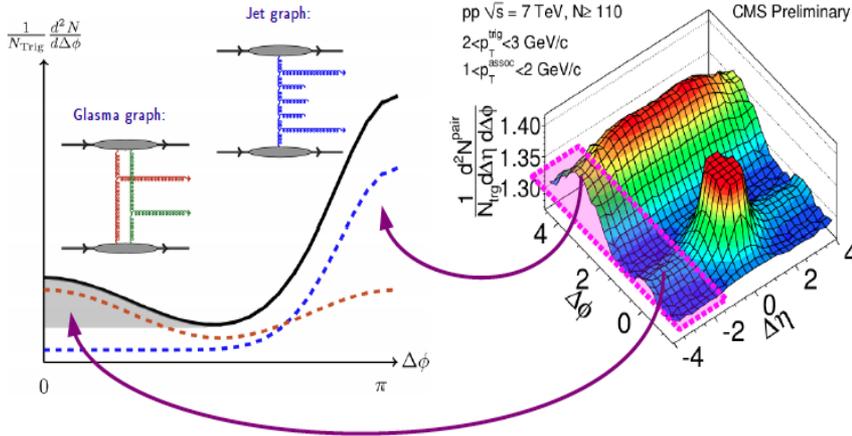
Gluon v_2 is translated
to hadron v_2

Mass splitting in $\langle p_T \rangle$
and v_2 !



Initial state descriptions of the ridge

- ◆ Several aspects of the ridge can be explained as an initial state effect



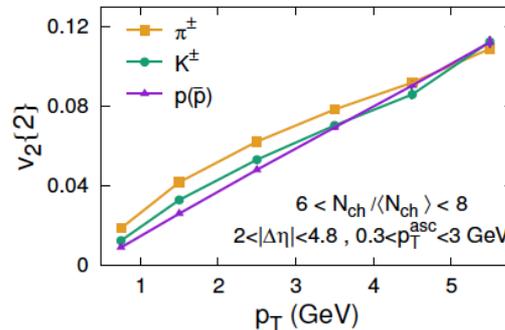
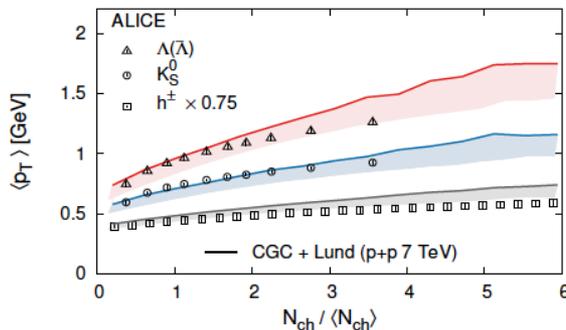
K. Dusling & R. Venugopalan, PRD87 (2013) no. 9, 094034 (174 cites), PRD87 (2013) no.5, 054014 (137 cites), ibid., no.5,051502 (102 cites)

Dusling, Tribedy, Venugopalan, PRD93 (2016) no.1, 014034

- ◆ Comparative study of initial state frameworks

Lappi, Schenke, Schlichting, Venugopalan, JHEP1601 (2016) 061

- ◆ Novel CGC+PYTHIA framework describes simultaneously mass ordering of $\langle p_T \rangle$ and v_n – believed to be signature of collective flow



Schenke, Schlichting, Tribedy, Venugopalan, arXiv:1607.02496

Probing the properties of matter through the analysis of conserved charge fluctuations

Taylor expansion of the **QCD** pressure: $\frac{P}{T^4} = \frac{1}{VT^3} \ln Z(T, V, \mu_B, \mu_Q, \mu_S)$

$$\frac{P}{T^4} = \sum_{i,j,k=0}^{\infty} \frac{1}{i!j!k!} \chi_{ijk}^{BQS}(T) \left(\frac{\mu_B}{T}\right)^i \left(\frac{\mu_Q}{T}\right)^j \left(\frac{\mu_S}{T}\right)^k$$

cumulants of net-charge fluctuations and correlations: $\chi_{ijk}^{BQS} = \left. \frac{\partial^{i+j+k} P/T^4}{\partial \hat{\mu}_B^i \partial \hat{\mu}_Q^j \partial \hat{\mu}_S^k} \right|_{\mu_{B,Q,S}=0}$

cumulant ratios:

$$R_{nm}^X(T, \mu_B) = \frac{\chi_n^X(T, \mu_B)}{\chi_m^X(T, \mu_B)}$$

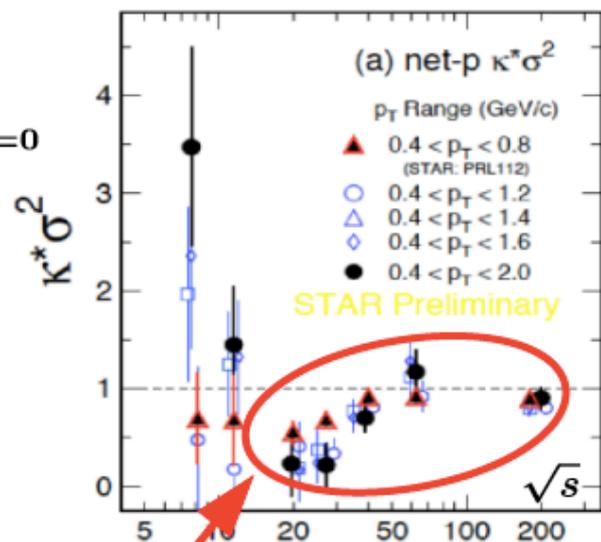
→ Taylor expansion of cumulant ratios

$M_X \sim \chi_1^X$: mean

$\sigma_X^2 \sim \chi_2^X$: variance

$S_X \sim \chi_3^X / (\chi_2^X)^{3/2}$: skewness

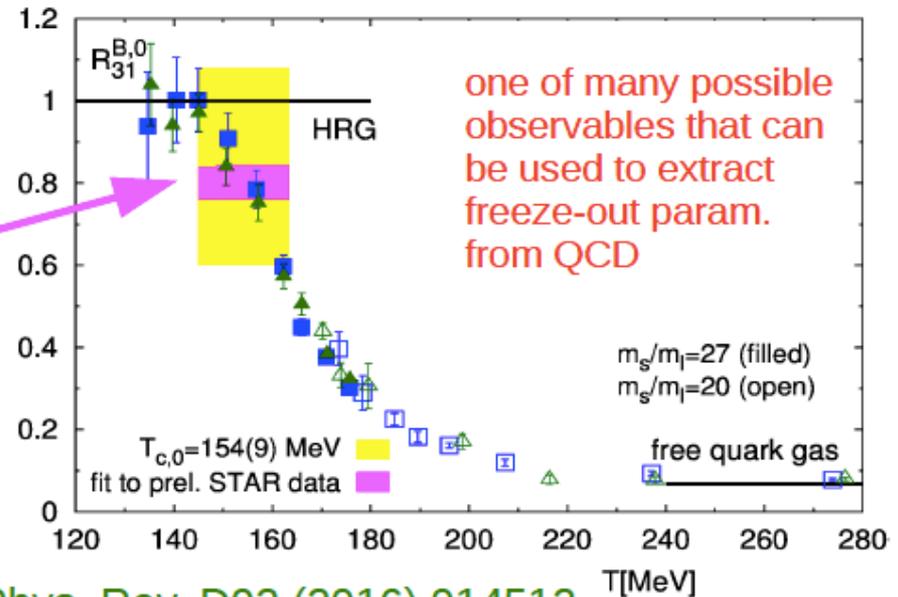
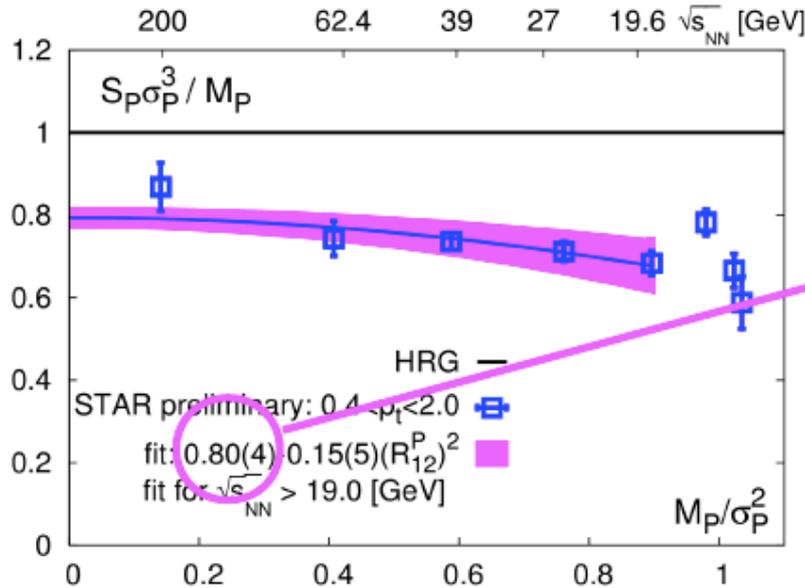
$\kappa_X \sim \chi_4^X / (\chi_2^X)^2$: kurtosis



QCD thermodynamics in a next-to-leading order Taylor expansion ?

Conserved charge fluctuations and freeze-out mean, variance and skewness

NLO Taylor expansion $S_B \sigma_B = \frac{\chi_4^B}{\sqrt{\chi_2^B}} \frac{M_B}{\sigma_B^2} \Rightarrow S_B \sigma_B = R_{31}^{B,0} \frac{S_B \sigma_B^3}{M_B} + \dots$



A. Bazavov et al. (BNL-Bielefeld-CCNU), Phys. Rev. D93 (2016) 014512

F. Karsch, Quark Matter 2015, arXiv:1512:06987

STAR data on proton number fluctuations are inconsistent with HRG model, however data at $\sqrt{s_{NN}} \geq 19.6$ GeV are consistent with QCD thermodynamics & freeze-out in the crossover region $T_c = (154 \pm 9)$ MeV

- intercept at $\mu_B = 0$ less than 1
- negative curvature as function of mean/variance

$$M_X \sim \chi_1^X : \text{mean}$$

$$\sigma_X^2 \sim \chi_2^X : \text{variance}$$

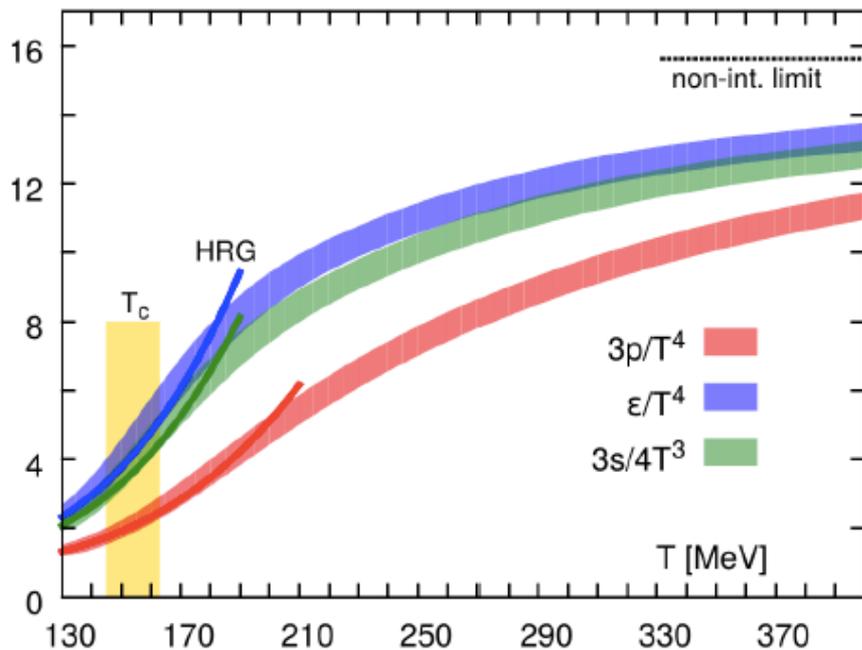
$$S_X \sim \chi_3^X / (\chi_2^X)^{3/2} : \text{skewness}$$

$$\kappa_X \sim \chi_4^X / (\chi_2^X)^2 : \text{kurtosis}$$

Equation of state of (2+1)-flavor QCD

pressure, entropy & energy density

$$\mu_B/T = 0$$

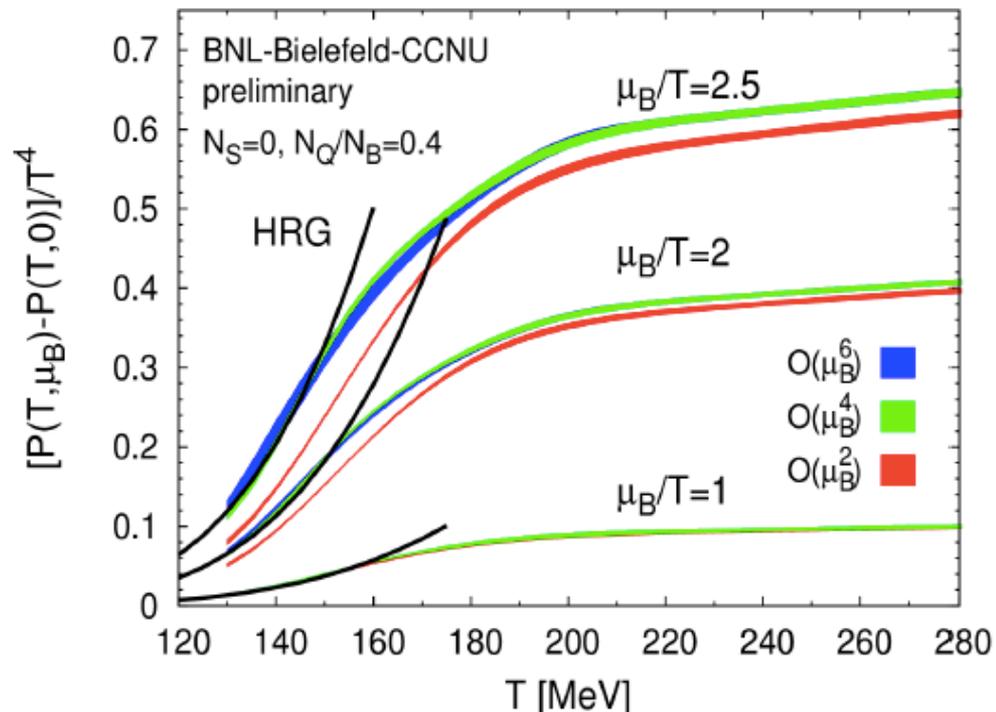


A. Bazavov et al. (hotQCD),
Phys. Rev. D90 (2014) 094503

EoS in (almost) the entire
range of energies covered
by **BEST@RHIC**

(ALCC project on Titan@ORNL
(S. Mukherjee et al.))

$$\mu_B/T > 0 \quad 6^{\text{th}} \text{ order Taylor series}$$

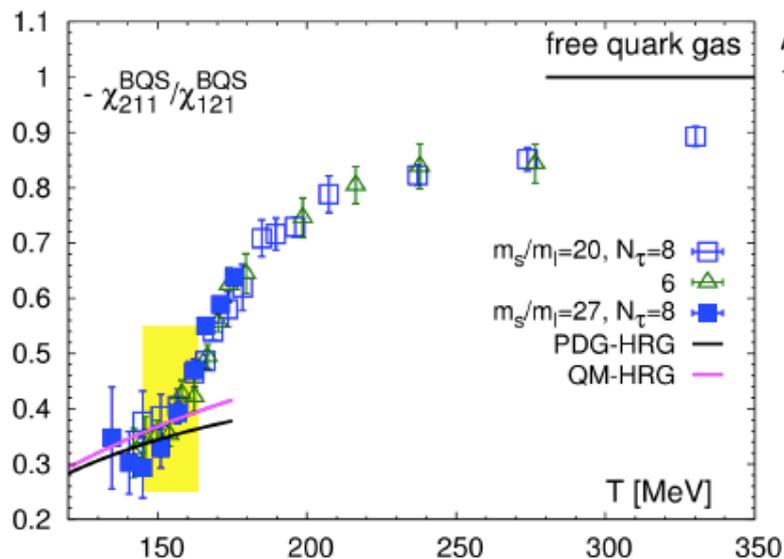


presented at Strange Quark Matter 2016
and Lattice 2016



The EoS is well controlled for $\mu_B/T \leq 2$
or equivalently $\sqrt{s_{NN}} \geq 20 \text{ GeV}$

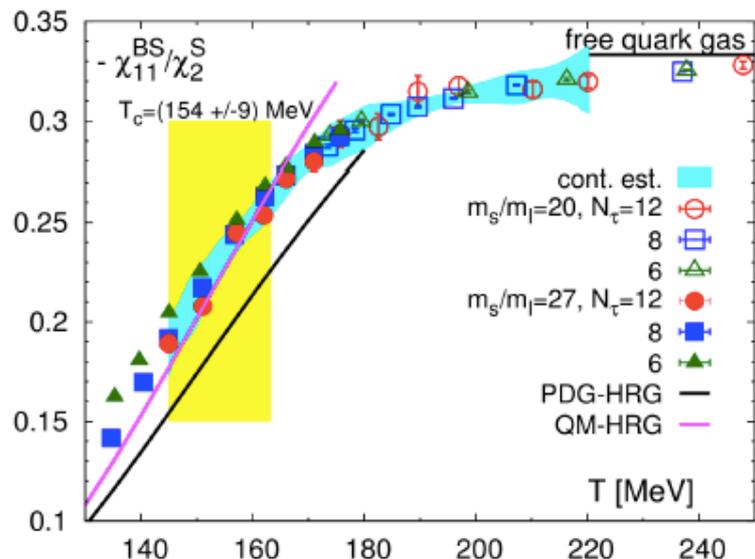
Analyzing **strangeness carrier** with higher order cumulants



$T > T_c$: Is strangeness carried by **quasi-particles** with quantum numbers of **quarks** ?

$$\frac{\chi_{211}^{BQS}}{\chi_{121}^{BQS}} = \begin{cases} -1, & T \rightarrow \infty \\ \simeq 0.3, & \text{HRG}, T \leq T_c \end{cases}$$

ratio of properly weighted charged, strange baryons



$T < T_c$ Who carries **strangeness in the HRG**?

strange baryon over total strangeness ratio:

significant deviations from a HRG based on known resonances (PDG-HRG)

Enhanced strange baryon fluctuations:

indication for more strange hadron resonances as predicted in quark model calculations (QM-HRG)

A. Bazavov et al.(BNL-Bielefeld-CCNU),
Phys. Rev. Lett. 113, 072001 (2014), arXiv:1404.6511

similar results for charmed baryons:
A. Bazavov et al., Phys.Lett. B737 (2014) 210

Postdocs and students

❑ Post-docs:

V. Skokov (left Sept. 2013, Asst. Prof. at W. Michigan U.)

Y.-Q. Ma (left on Aug. 2014, Asst Prof. at Peking U.)

M. Hentschinski (left on Sept. 2014, post-doc at UNAM, Mexico)

G. Denical (left May, 2016, Junior faculty in Brazil his home country.)

S. Schlichting (leaves on Sept. 3, 2016, Five-year Fellow at U. of Washington)

Y. Yin (leaves on September 30, Postdoc at MIT)

M. Sievert (leaves on Sept. 30, 2016, postdoc at Los Alamos National Lab)

LGT group ...

❑ Students:

H. Zhang (Ph.D. 2014, Qiu, post-doc at Ohio State U)

Dima's students ...

M. Mace (SB student, Kharzeev joint with Venugopalan)